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COMPUTER PROGRAM FOR PREDICTION OF FUEL CONSUMPTION  
STATISTICAL DATA FOR AN UPPER STAGE THREE-AXES  
STABILIZED ON-OFF CONTROL SYSTEM

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COMPUTER PROGRAM FOR PREDICTION OF FUEL CONSUMPTION STATISTICAL DATA  
FOR AN UPPER STAGE THREE-AXES STABILIZED ON-OFF CONTROL SYSTEM

by R. N. Knauber  
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SUMMARY

This report describes a FORTRAN coded computer program and method to predict the reaction control fuel consumption statistics for a three axis stabilized rocket vehicle upper stage. It uses a Monte Carlo approach which is made more efficient by using closed form estimates of impulse useage. It includes effects of rocket motor thrust misalignment, static unbalance, aerodynamic disturbances, and deviations in trajectory, mass properties and control system characteristics. This routine has been used for over a decade to accurately predict the control fuel consumption statistics for the Scout launch vehicle second and third stage reaction control systems.

By selection of input data and options this routine can be applied to many types of on-off reaction controlled vehicles.

The psuedo random number generation and statistical analyses subroutines including the output histograms can easily be used for other Monte Carlo analyses problems.

A typical run of 200 samples requires 2 seconds of central processor time on a CDC CYBER 175 computer.

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LIST OF SYMBOLS

a	limit cycle rate (deg/sec)
$C_{N_\alpha}^S$	aerodynamic normal force coefficient slope with angle of attack times reference area (ft <sup>2</sup> /radian)
$C_D^S$	aerodynamic drag coefficient times reference area (ft <sup>2</sup> )
DC	duty cycle
d	deadband halfwidth (degrees)
e	control error signal (degrees)
F	control force (lb <sub>f</sub> )
g	gravitational acceleration (ft/sec <sup>2</sup> )
H	control switching hysteresis ratio (1 - d <sub>off</sub> /d <sub>on</sub> )
h	altitude (feet)
I	moment of inertia (slug-ft <sup>2</sup> )
I <sub>cap</sub>	impulse required for capture maneuver (lb <sub>f</sub> -sec)
I <sub>sp</sub>	control fuel specific impulse (lb <sub>f</sub> -sec/lb <sub>m</sub> )
K <sub>R</sub> /K <sub>D</sub>	control system rate to displacement gain ratio (seconds)
K	a constant
l <sub>c</sub>	control moment arm (feet)
N	number
P	probability level
PW	control motor firing pulse width (seconds)
Q	dynamic pressure (lbs <sub>f</sub> /ft <sup>2</sup> )
R <sub>c</sub>	roll control moment arm (inches)
R <sub>o</sub>	earth radius (feet)
RND	random normal deviate
RTI	booster induced roll angular impulse (ft-lb <sub>f</sub> -sec)
SU	static unbalance (ft-lbs <sub>f</sub> )
s	sample population standard deviation

### LIST OF SYMBOLS (Cont.)

T	booster thrust (lb <sub>f</sub> )
T <sub>1</sub>	total system turn-on time delay (seconds)
T <sub>2</sub>	total system turn-off time delay (seconds)
t	time (seconds)
V	velocity (ft/sec)
W	weight of vehicle (unsubscripted) (lbs)
W <sub>i</sub>	control fuel weight (subscripted) (lbs)
x	body station measured positive toward tail (inches)
z	normal location on body from centerline (inches)

### Greek Letters

$\alpha$	angle of attack (degrees)
$\beta$	angle of sideslip (degrees)
$\gamma$	flight path angle measured from local horizontal (degrees)
$\Delta$	incremental change
$\epsilon$	misalignment angle of thrust (degrees)
$\zeta$	azimuth (degrees)
$\theta$	pitch attitude (degrees)
$\lambda$	forward cant angle of control motors (degrees)
$\pi$	ratio of circular circumference to diameter
$\rho$	atmospheric density (slugs/ft <sup>3</sup> )
$\rho_{xy}$	correlation coefficient of x versus y variable
$\sigma$	standard deviation
$\phi$	roll attitude (degrees)
$\psi$	yaw attitude (degrees)



## LIST OF SYMBOLS (Cont.)

### Subscripts

boost	during boost phase
C	control
CAP	associated with capture transient
coast	associated with coast period
cg	center of gravity
cp	aerodynamic center of normal force
D	disturbance
db	due to deadband
e	error
jet	control motor thrust
p	pitch
pr	predicted
R	roll
RETRO	retro following coast period
r	booster thrust
W	wind
x	roll axis
y	yaw or transverse
o	initial value
1	start or on
2	end or off

### Special Notation

.	dots above a parameter denote differentiation with respect to time.
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## 1.0 INTRODUCTION

Reaction control system fuel consumption predictions for missiles, launch vehicles and space vehicles is usually required to be accurate so that weight can be minimized without unduly sacrificing mission success probability. Almost all reaction controlled missiles, launch vehicles and spacecraft would result in loss of control and mission failure if the control fuel useage were seriously underpredicted. On many vehicles overprediction of fuel requirements results in costly weight and volume penalties. The control system designer requires an accurate prediction of the statistical distribution of required impulse or control fuel to size the system. For missions with different coast periods a prediction of fuel useage is needed for propellant loading.

The method and computer program for predicting reaction control system fuel consumption statistics presented in this report has been used over the past fifteen years for the Scout launch vehicle second and third stage reaction control systems. Predictions using this method correlate well with flight data statistics. There is a slight tendency of the method to be conservative particularly at the low end of the probability distribution. This is due to an assumption of symmetric attitude limit cycle motion when undisturbed. In actuality a certain small percentage of vehicles achieve a near zero duty cycle in an axis rather than a symmetric limit cycle. As a result fuel consumption can be lower than the minimum predicted by the method.

Prediction of control fuel by this method is only as good as the accuracy of the input data; i. e., "Garbage in - garbage out." Scout experience in accurate prediction results from accurate knowledge of disturbance statistics, particularly rocket booster motor thrust misalignment. These are derived from detailed post-flight data analyses.

## 2.0 METHODOLOGY

The Monte Carlo method, used herein, is a relatively straightforward approach for predicting the statistical outcome of a highly non-linear process involving many variables. On-off reaction control system fuel consumption prediction for an upper stage rocket booster vehicle is a good candidate for this method. Large amounts of computer time are normally associated with the Monte Carlo approach. The method described herein is made efficient by using a series of closed form approximations to the fuel consumption during transient maneuvers and steady state operation. As a result several hundred samples can be computed with a few seconds of computer time on a high speed digital computer. Assumptions and equations used in the computer program are described in the following paragraphs.

### 2.1 Fuel Consumption Assumptions

Many assumptions are made to simplify the control fuel consumption prediction process. These include:

- . Uncoupled axes (pitch, yaw, roll) each having its own set of control motors.
- . On-off control has a simple deadband with constant switching slope for each phase of the flight (boost and coast) (see phase plane Figure 1).
- . When undisturbed each axis control achieves a symmetric limit cycle motion.
- . Disturbing torques and impulses are balanced by the control system without exceeding the zero rate deadband attitude error.
- . Disturbing torques of sufficient magnitude to cause deadband crossing results in fuel consumption based on angular impulse balance plus symmetric limit cycle motion (Figure 1).
- . When sets of reaction control motors are shared by two or more axes, each axis has full use of the motors in an uncoupled sense (e.g., yaw-roll mixing with four (4) jets is decomposed into a yaw-axis control with 2 motors in each sense and roll axes control with 2 motors forming a couple in each sense or direction).
- . Sensor, computational, filter, and control motor switching hardware responses are treated as a simple equivalent time transport lag.
- . Structural mode coupling with the control system is limited. An effective time transport lag is assumed to adequately account for structurally coupling. This is the case for the Scout launch vehicle (see Appendix D of Reference 1).
- . Reaction control motor pulse shapes can be expressed as an equivalent square wave with appropriate thrust level and time delays.
- . Aerodynamic stability derivatives are linear and can be expressed as a constant normal force coefficient slope with angle of attack and a constant aerodynamic center location.

- The vehicle is axisymmetric in terms of moments of inertia and aerodynamic configuration.
- Trajectory parameters are as input and are not significantly perturbed by the off-nominal control behavior.
- Changing control fuel consumption does not alter the vehicle mass properties.
- Aerodynamic angle of attack includes the attitude error equal to the deadband halfwidth.

## 2.2 Equations

Equations describing the disturbances and fuel consumption are presented below. Trajectory geometry and definition of angles are presented in Figure 2.

### 2.2.1 Attitude Control Acceleration

Control angular accelerations are:

$$(2-1) \quad \theta_c, \psi_c = \frac{F_c \varrho_c}{12I_y}$$

$$(2-2) \quad \phi_c = \frac{2F_c R_c}{12I_x}$$

where,

$$\varrho_c = [(X_c - X_{cg}) \cos \lambda + Z_c \sin \lambda] / 12$$

## 2.2.2 Disturbances

Disturbing accelerations are due to booster thrust misalignment, vehicle static unbalance and aerodynamic torques.

$$(2-3) \quad \dot{\theta}_D = \frac{1}{I_y} \left[ \frac{T \epsilon_{\tau p} (X_{\tau} - X_{cg})}{57.3 (12)} + \frac{T S U_p}{W} - \frac{C_{N\alpha} S Q \alpha (X_{cg} - X_{cp})}{12} \right]$$

$$(2-4) \quad \dot{\psi}_D = \frac{1}{I_y} \left[ \frac{T \epsilon_{\tau y} (X_{\tau} - X_{cg})}{57.3 (12)} + \frac{T S U_y}{W} - \frac{C_{N\alpha} S Q \beta (X_{cg} - X_{cp})}{12} \right]$$

$$(2-5) \quad \phi_D = \frac{1}{I_x} \left\{ \frac{T}{57.3 W} (\epsilon_{\tau y} S U_p - \epsilon_{\tau p} S U_y) + \frac{C_{N\alpha} S Q}{W} \left( \alpha \frac{S U_y}{W} + \beta S U_p \right) + S U_y \left[ \frac{T}{\ell_c W} \left( \epsilon_{\tau p} \frac{(X_{\tau} - X_{cg})}{12} \right) + \frac{S U_p}{W} \right] + \frac{C_{N\alpha} S Q \alpha (X_{cg} - X_{cp})}{\ell_c W} \right. \\ \left. - S U_p \left[ \frac{T}{\ell_c W} \left( \epsilon_{\tau y} \frac{(X_{\tau} - X_{cg})}{12} \right) + \frac{S U_y}{W} \right] - \frac{C_{N\alpha} S Q \beta (X_{cg} - X_{cp})}{\ell_c W} \right\}$$

Angles of attack and sideslip are:

$$(2-6) \quad \alpha = \theta_{PR} - \gamma_{PR} - \gamma_{e1} + \alpha_W + \Delta \alpha_{db}$$

$$(2-7) \quad \beta = \beta_{PR} + \zeta_{e1} \cos \gamma_{PR} + \beta_W + \Delta \beta_{db} \quad (\text{see Figure 2})$$

where  $\gamma_{e1}$  is the perturbation flight path angle from previous stages plus the integrated change in flight path angle due to pointing error (deadband).

$\zeta_{e1}$  is the equivalent flight path deviation in the yaw plane.

$$(2-8) \quad \gamma_{e1} = \frac{57.3}{V} \left[ \frac{\gamma_{e0} V_0}{57.3} + \int \frac{T \theta_e}{W/g} dt \right]$$

$$(2-9) \quad \zeta_{e1} = \frac{57.3}{V} \left[ \frac{\zeta_{e0} V_0}{57.3} + \int \frac{T \psi_e}{W/g} dt \right]$$

Angles of attack and sideslip due to wind are:

$$(2-10) \quad \alpha_W = 57.3 \frac{V_W \sin \gamma_{PR} \cos (\zeta_W - \zeta_{PR})}{V + V_W \cos \gamma_{PR} \cos (\zeta_W - \zeta_{PR})}$$

$$(2-11) \quad \beta_W = 57.3 \frac{V_W \sin (\zeta_W - \zeta_{PR})}{V + V_W \cos \gamma_{PR} \cos (\zeta_W - \zeta_{PR})}$$

Incremental angles of attack and sideslip due to pointing errors are:

$$(2-12) \quad \Delta\alpha_{db} = \pm d - (\gamma_e - \gamma_{e1})/2$$

$$(2-13) \quad \Delta\beta_{db} = \pm d + (\zeta_e - \zeta_{e1})/2$$

### 2.2.3 Control System Duty Cycles

Control system duty cycles during boost include those due to disturbance torque balance and undisturbed limit cycle behavior.

$$(2-14) \quad DC_P = \frac{|\dot{\theta}_D|}{\theta_C} \quad ; \quad |\dot{\theta}_D| \geq \dot{\theta}_{TEST}$$

$$(2-15) \quad DC_P = \frac{|\dot{\theta}_D|}{\dot{\theta}_C} + DC_P(LIMIT CYCLE) \cdot |\dot{\theta}_D| < \dot{\theta}_{TEST}$$

Test accelerations are those disturbing accelerations which define the boundary between a one-sided motor firing and crossing the deadband as shown in Figure 1 and 3.

### 2.2.4 Limit Cycle Motion

Undisturbed limit cycle motion results in a duty cycle dependent on control system characteristics.

$$(2-16) \quad DC_{P(LIMIT CYCLE)} = \frac{K_1}{1 + \frac{K_1 \theta_C}{a} \left( \frac{d}{a} + T_1 - K_R/K_D \right)}$$

where,

$$(2-17) \quad a = \frac{K_1 \ddot{\theta}_C T_2 (K_R/K_D - T_2/2) + dH}{2 K_R/K_D - T_1 - T_2}$$

$$K_1 = 1 \quad \text{for square wave pulse of control motor}$$

$$(2-18) \quad K_1 = 1 + \frac{t_p}{PW 2\pi} (\pi - \nu - 2 \sin \nu) \quad \text{for thrust with overshoot (Figure 4)}$$

$$(2-19) \quad PW = \frac{2a}{K_1 \dot{\theta}_C}$$

$$(2-20) \quad \nu = \tan^{-1} \left[ \frac{\pi}{\ln \left( \frac{1}{F_p/F_c - 1} \right)} \right]$$

With control motor thrust overshoot the above equations for duty cycle are computed with one iteration starting with  $K_1 = 1$ .

When control acceleration is very high, long delay times can result in a deadband overshoot condition; i. e., the error signal crosses the total deadband before the opposite motor actually turns off. The control acceleration at which this occurs is:

$$(2-21) \quad \ddot{\theta}_{C_{MAX}} = \frac{d[2 K_R/K_D - T_1 - T_2 - H (K_R/K_D - T_2/2)]}{T_2 (K_R/K_D - T_2/2) (K_R/K_D - T_1/2)}$$

If  $\ddot{\theta}_C > \ddot{\theta}_{C_{MAX}}$ , the duty cycle becomes,

$$(2-22) \quad DC_p = \frac{1}{1 + \frac{T_1 - T_2 - A}{2T_2 - A + \frac{1}{K_R/K_D} \left[ \frac{A}{2} + (T_2 - A) \right] (T_1 - T_2 + A)}}$$

where,

$$(2-23) \quad A = \frac{2d(1 - H/2)}{\theta_C K_R/K_D}$$

Equations for yaw and roll duty cycles are the same.

#### 2.2.5 Fuel Consumption

Control fuel consumption is dependent on the total impulse and effective specific impulse of the control motors. The specific impulse of the control motors used for pitch and yaw is assumed to be the same. A separate roll motor specific impulse can be used. In most cases the specific impulse during coast is different than during boost. Boost fuel consumption is:

$$(2-24) \quad W_{BOOST} = W_{BOOST_p} + W_{BOOST_y} + W_{BOOST_R}$$

For pitch and yaw the fuel consumed is:

$$(2-25) \quad W_{BOOST_p} = \frac{1}{I_{SP}} \left[ \int F_{C_p} DC_p dt + I_{CAP_p} \right]$$

where  $I_{cap}$  is the additional impulse needed to "capture" at separation/ignition from the initial conditions on rate and displacement,

$$(2-26) \quad I_{CAP_p} \approx \frac{F_C}{|\ddot{\theta}_C|} \left[ \left| \dot{\theta}_0 + \frac{2(\theta_0 - d)}{K_R/K_D} \right| + 2 \left| \dot{\theta}_C \right| T_2 \right]$$

Roll fuel consumption includes an amount for booster roll torque (RTI) and pitch and yaw motor misalignment.

$$(2-27) \quad W_{\text{BOOST}_R} = \frac{1}{I_{\text{SP}_R}} \left[ \int F_{C_R} DC_R dt + I_{\text{CAP}_R} + \text{RTI} \right. \\ \left. + |\epsilon_{\text{JET}_P}| \left| \frac{Z_C}{R_C} \int F_{C_P} DC_P dt + |\epsilon_{\text{JET}_Y}| \left| \frac{Z_C}{R_C} \int F_{C_Y} DC_Y dt \right| \right]$$

During the coast phase a symmetric limit cycle is assumed. Coast fuel consumption also includes (1) an incremental amount for transients due to deadband reduction from boost to coast system, (2) guidance program attitude rate changes in pitch and yaw, and (3) an optional retro maneuver with the boost pitch and yaw control motors.

$$(2-28) \quad W_{\text{COAST}} = \frac{\int F_{C_P} DC_P dt}{I_{\text{SP}_P}} + \frac{\int F_{C_Y} DC_Y dt}{I_{\text{SP}_Y}} + \frac{\int F_{C_R} DC_R dt}{I_{\text{SP}_R}} + W_{\text{RETRO}} + \Delta W_i$$

$$(2-29) \quad W_{\text{RETRO}} = 2 \left| F_{C_P} + F_{C_Y} + F_{C_R} \right| \frac{t_{\text{RETRO}}}{I_{\text{SP}_{\text{RETRO}}}}$$

This assumes that the four boost pitch and yaw motors fire continuously and the system operates at a 100 percent duty cycle. Additional fuel for deadband reduction and torquing rate changes for each axis is

$$(2-30) \quad \Delta W_i \cong \frac{F_C}{I_{\text{SP}}} \left[ 2 T_2 + \frac{\left| \Delta \dot{\theta}_C + 57.3 a_b + \frac{2(d_b - d_c)}{K_R/K_D} \right|}{57.3 \dot{\theta}_C} \right]$$

where  $\Delta \dot{\theta}$  is the change in guidance pitch or yaw program rate (deg/sec)

$a_b$  is the boost system limit cycle rate (rad/sec)

$d_b, d_c$  is the boost and coast system deadband halfwidth (degrees)

$K_R/K_D$  is the coast system rate to displacement gain ration (sec)

$\ddot{\theta}_C$  is the coast system control acceleration (rad/sec<sup>2</sup>)



## 2.2.6 Trajectory and Vehicle Characteristics

Time histories of pertinent trajectory and vehicle characteristics are input to use in the calculations. These include dynamic pressure, velocity, booster thrust and propellant weight remaining, altitude, flight path angle, and azimuth. Wind velocity versus altitude is also input. Thrust misalignment is assumed to be described as an initial value and a slope which is correlated (see section 2.3).

Mass properties (center of mass station and transverse moment of inertia is assumed to be a second order polynomial of fraction of booster propellant consumed.

Given a three point curve  $(x_1, y_1)$ ,  $(x_2, y_2)$  and  $(x_3, y_3)$  the second order function is,

$$(2-31) \quad y = y_1 + K_1 x + K_2 x^2$$

where,

$$(2-32) \quad K_2 = \frac{y_3 - y_1 - \frac{x_3}{x_2} (y_2 - y_1)}{(x_3^2 - x_2 x_3)}$$

and,

$$(2-33) \quad K_1 = \frac{(y_2 - y_1)}{x_2} - K_2 x_2$$

The independent variable ( $x$ ) is the fraction of booster propellant consumed, and the dependent variable is either center of mass station or the moment of inertia. The three input points should include the 0, 0.5 and 1.0 fractional propellant consumed values for best results. The burnout, or 1.0 fractional propellant consumed, values are used for coast calculations.

## 2.2.7 Optional Trajectory Characteristics

An optional input for certain trajectory calculations is available to approximate dynamic pressure, altitude and flight path angle. This option is used primarily where many parametric runs are required for which there are no trajectories. Given the initial flight path angle ( $\gamma_0$ ), velocity ( $V_0$ ) and dynamic pressure ( $Q_0$ ) the density at ignition is calculated.

$$(2-34) \quad \rho_0 = \frac{2Q_0}{V_0^2}$$

This density is used with a standard atmosphere logarithmic density versus altitude data set to obtain initial altitude. Thrust, weight, and drag coefficient ( $C_D S$ ) are input and used to propagate a gravity turn trajectory.

The set of first order equations used to propagate the trajectory is:

$$(2-35) \quad \dot{V} = \frac{g_0(T - C_D S Q)}{W} - g \sin \gamma$$

$$(2-36) \quad \dot{h} = -57.3 \frac{g \cos \gamma}{V}$$

$$(2-37) \quad \dot{\gamma} = V \sin \gamma$$

where,

$$(2-38) \quad Q = \frac{1}{2} \rho V^2$$

$$(2-39) \quad g = \frac{g_0}{1 + \left(\frac{h}{R_0}\right)^3}$$

and,

$$g_0 = 32.174 \text{ ft/sec}^2$$

$$R_0 = 20,919,668 \text{ ft}$$

A Runge-Kutta integration subroutine is used to integrate these equations during boost to obtain the nominal trajectory parameters ( $V, h, \gamma, Q$ ).

## 2.3 Statistical Analysis

The analysis method used in this routine is the Monte Carlo Technique. It is based on random sampling of a set of random input variables for the vehicle, trajectory, disturbances, and control system and computing the resulting total fuel consumption, boost fuel, coast fuel, and retro time. By computing a large number of such flights the statistical variation of fuel consumption is obtained. The method of treatment of input variables and analysis of output is listed below.

### 2.3.1 Input Random Variables

There are many random variables required as input. These variables are assumed to be Gaussian (Normal Distribution Function). A mean and standard deviation is entered for each of these variables. In all cases except booster thrust misalignment each variable is uncorrelated with all other variables.

For uncorrelated variables the random sample is:

$$(2-40) \quad x = \bar{x} + \text{RND } \sigma_x$$

where  $\bar{x}$  is the mean value of  $x$   
 $\sigma_x$  is the standard deviation of  $x$   
 $\text{RND}$  is a random normal deviate (computed by routine)

Where there is a correlation between two variables as in the case of thrust misalignment the random samples are,

$$x = \bar{x} + \text{RND}_1 \sigma_x$$

$$(2-41) \quad y = \bar{y} + \text{RND}_1 \sigma_y \rho_{xy} + \text{RND}_2 \sigma_y \sqrt{\frac{N-1}{N-2} (1 - \rho_{xy}^2)}$$

where  $\rho_{xy}$  is the correlation coefficient of the  $x$  and  $y$  variables  
 $N$  is the number of samples used to derive the correlation coefficient

The following is a list of random variables for input:

$\epsilon_{r_0}$	initial value of booster thrust misalignment
$\dot{\epsilon}_r$	slope of booster thrust misalignment with time
$\dot{\theta}_0, \dot{\psi}_0, \dot{\phi}_0$	initial pitch, yaw and roll rate
$\theta_e, \psi_e, \phi_e$	initial attitude error in pitch, yaw, and roll
$\gamma_e, \zeta_e$	initial flight path and azimuth error
$Q_{\text{FRACT}}$	dynamic pressure fractional deviation ( $Q/Q_{\text{pr}}$ )
$I_y$	transverse moment of inertia
$x_{\text{cg}}$	center of mass station
$SU_p, SU_y$	pitch and yaw static unbalance
$\text{RTI}$	booster roll torque impulse
$\epsilon_{\text{JET}}$	boost control motor misalignment angles
$V_w$	wind velocity versus altitude
$\zeta_w$	wind direction
$F_c$	control motor force levels
$I_{\text{sp}}$	control motor specific impulse, boost and coast
$F_p/F_c$	pitch and yaw control motor overshoot ratio
$t_p$	pitch and yaw control motor time from on to peak thrust
$t_{1m}$	control motor effective turn on time delay
$t_{2m}$	control motor effective turn-off time delay
$t_f$	autopilot filter effective time delay
$t_{\text{RG}}$	autopilot rate gyro effective time delay
$K_R/K_D$	autopilot rate to displacement gain ratio
$d$	control system deadband halfwidth
$H$	switching hysteresis fraction

Other input variables are not treated as random.

### 2.3.2 Output Statistical Analysis

The routine calculates boost, coast, and total fuel consumption for N samples (flights). The output includes the values of fuel consumption with the calculated discrete probability levels for the N samples. In addition to these discretes, the sample population mean, standard deviation, skewness, and kurtosis are output for the parameters and the logarithm of the parameters. The probability distribution function parameters and key probability levels are based on three distribution functions; (1) Normal, (2) Log-Normal, and (3) Weibull. An equivalent level of significance for each of these three distributions functions is estimated and output based on the CHI-Squared Goodness of Fit Test.

When the fuel consumption samples are arranged in ascending order, the probability that the fuel consumption will be under a particular value is given by the following equation:

$$(2-42) \quad P(\text{fuel consumption} < W_1) = \frac{N_1}{N+1}$$

where,  $W_1$  is a particular value of fuel consumption.

$N_1$  is the sample number corresponding to  $W_1$  in the arranged fuel consumption distribution.

$N$  is the total number of samples calculated.

It is desirable to obtain confidence intervals about a given probability level. This is also a function of the sample size. The two sided confidence interval for the standard deviation ( $\sigma$ ) of a population of sample size N extracted from a Normal Distribution Function is provided by the following equation:

$$(2-43) \quad \frac{\sigma}{s_x} = \frac{1}{\sqrt{1 \pm k_\gamma \sqrt{\frac{2}{N-1}}}}$$

where,

$s_x$  is the sample standard deviation calculated from N samples.

$\sigma$  is the true standard deviation.

$k_\gamma$  is the number of standard deviations on a Normal Distribution which provide a probability level equal to the confidence coefficient (i.e., 0.95 confidence -  $1.96\sigma$ ,  $k_\gamma = 1.96$ ). If only one side of the confidence interval (high side) is desired, the values of  $k_\gamma$  become based on cumulative Normal Distribution probabilities.

The confidence limits for other probability levels can be established assuming normality. That is, once the standard deviation is established with an upper confidence limit (say 95 percent) then the value at another probability level can be expressed as a number of standard deviations from the mean.

$$(2-44) \quad y' = \bar{y} + \frac{K s_x}{\sqrt{1 + k_\gamma \frac{2}{N-1}}}$$

(95% confidence  $k_\gamma = 1.645$  for one sided upper limit of confidence interval.)

where  $y'$  is the value of parameter 'y' at a probability level equivalent to the mean plus 'K' standard deviations on a Normal Distribution with the desired confidence coefficient.

$\bar{y}$  is the sample mean (assumed to be the true mean value of the distribution function).

K is the number of standard deviations required to provide the desired probability level.

The following is a short table for values of 'K' and 'k' for various probability levels and confidence coefficients.

Probability Level	K, $k_\gamma$ (one-sided)
0.500	0
0.900	1.282
0.950	1.645
0.995	2.575
0.999	3.090

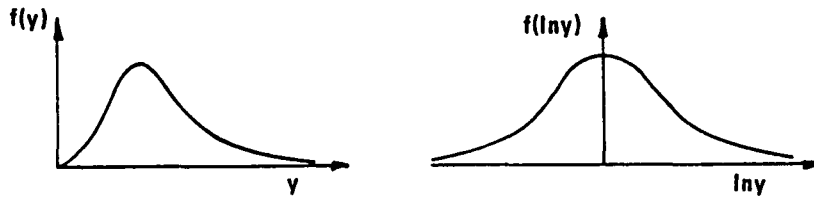
For example, to find the value of 'y' at 99.5% probability at 95 percent confidence, given sample mean,  $\bar{y}$ , and variance,  $S_x^2$ , from N samples

$$(2-45) \quad y' = \bar{y} + \frac{2.575 s_x}{\sqrt{1 - 1.645 \frac{2}{N-1}}}$$

In the case of fuel consumption, the distribution function is not usually Gaussian (Normal Distribution). Therefore, several approximate distribution functions are tested in the routine based on the Chi-Squared Goodness of Fit Test. These include the Normal, Log-Normal and three parameter Weibull distribution. The Log-Normal Distribution is simply a transformation of the 'y' parameter to the logarithm of 'y'. As shown in the sketch below, if the probability density function is one sided, the density function of the log 'y'

may approximate a Normal Distribution. If this occurs the properties of the Normal Distribution function such as probability level and confidence coefficient, can be applied to log 'y'.

#### Log-Normal Density Function



The three parameter Weibull distribution is also used. This distribution function is described in detail in Reference (2). The cumulative probability distribution function and density function can be described in terms of three parameters 'a', 'b', and 'c' by the following equations.

$$(2-46) \quad f(y) = \frac{c}{b} A e^{-A} \quad \text{density function}$$

$$(2-47) \quad F(y) = 1 - e^{-A} \quad \text{distribution function}$$

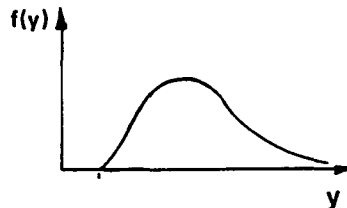
where,

$$A = \left( \frac{y - a}{b} \right)^c$$

and where 'a', 'b', 'c' are values greater than zero.

The probability density function can take on many shapes by varying the values of 'a', 'b', and 'c' and thus has application to a wide variety of problems. For this application it will have a shape similar to that shown in the sketch.

#### Weibull Density Function



For this distribution function the value of 'y' at a given probability level is given by:

$$(2-48) \quad y = a - b [\ln(1 - p)]^{1/c}$$

where P is the probability level.

The routine prints out the parameters 'a', 'b', and 'c' determined from the fit based on McClintock's method of Reference (2). It also prints out the values of the parameter at several key probability levels. Calculation of confidence intervals for this distribution function is not included in this routine.

In addition to the statistical analyses described above, histograms of the output are made on the line printer for ready comparison.

### 3.0 PROGRAM DESCRIPTION

#### 3.1 General

This routine is programmed in FORTRAN IV for the CDC CYBER 175 system. The only non-ANSI code used is the pseudo random number generator (RANF). An ANSI option for a replacement is identified in the program listing. The routine requires approximately 16 K words. Program flow, and user instructions are presented in the following paragraphs.

#### 3.2 Program Flow

The program flows straight forward in five basic parts.

- . Input option selection
- . Input of all data
- . Precalculation of boost phase time histories at integration steps
- . Monte Carlo calculation of specified number of cases of fuel consumption or coast time
- . Statistical analysis of results

Flow charts showing the general sequence are presented in Figure 5. A list of subroutines, their cross references and common blocks are presented in Figure 6. A description of the subroutines is given in the following paragraphs.

#### 3.3 Subroutine Description

Most of the repeated specialized calculations are performed in the seventeen subroutines. Subroutine and common reference map is presented in Figure 6. The descriptions of each follow in alphabetical order.

##### ALTI

'ALTI' is used by subroutine TABGEN when the input option requires generation of certain trajectory parameters. Given the dynamic pressure and velocity it computes the altitude based on the logarithm of inverse density versus altitude table (RHO) supplied in labeled common "DRH" defined in the 'TABGEN' subroutine.

The call to the subroutine is:

CALL ALTI (ALTO, VO, QO)

ALTO	-	is the altitude in feet computed by this subroutine.
VO	-	is the velocity input (ft/sec).
QO	-	is the dynamic pressure input (lbs/ft <sup>2</sup> ).



### ASCEND

This subroutine rearranges an array of numbers in monotonically increasing or decreasing order.

The call to this subroutine is:

CALL ASCEND (L, VAL, M)

L	-	is the number of values in array VAL (input).
VAL	-	is the array to be rearranged (input and output).
M	-	input option for ascending or descending order, M = 0 ascending M = 1 descending

### CALCU

This subroutine is used with "RUNGE" to calculate the trajectory state variables and their first derivatives in TABGEN. It is based on equations 2-35 through 2-39.

The call to this subroutine is:

CALL CALCU

Input and output is passed through labeled common blocks 'DDI', 'DDY', and 'DRH'. 'DDY' contains the state variables and time information.

### CHISQ

This subroutine is based on the Chi-Squared Goodness of Fit Test to a known distribution. It tests for level of significance against a Normal, Log Normal, and a Weibull distribution function.

The call to this subroutine is:

CALL CHISQ (N, A, CR, NG, AM, AS, WA, WB, WC, LD)

N	-	is the total sample size input.
A	-	is the input array of values.
CR	-	is the output computed level of significance.
NG	-	is the number of cells for the CHI-Squared Goodness of Fit Test.
AM	-	is the computed mean.
AS	-	is the computed standard deviation.
WA	-	is the Weibull 'a' parameter.
WB	-	is the Weibull 'b' parameter.
WC	-	is the Weibull 'c' parameter.

LD = 0 for a two parameter distribution (the Normal and Log-Normal).

LD = 1 for a three parameter distribution (Weibull).

Tables of the cumulative Normal probability distribution 'C' versus number of standard deviations 'Z' are embedded in this subroutine and are part of labeled common block 'CZ'.

### CYCLE

'CYCLE' computes the duty cycle for the on-off control during symmetric undisturbed limit cycle operation. It is based on equations 2-16 through 2-20. It includes the option for deadband overshoot and overshoot type control motor thrust response.

The call to this subroutine is:

CALL CYCLE (THEC, GR, DR, H, T1, T2, DC, A, NDOVER, FCT)

THEC	-	is the control acceleration ( $\text{rad/sec}^2$ ).
GR	-	is the rate to displacement gain ratio ( $K_R/K_D$ sec).
DR	-	is the deadband halfwidth (rad).
H	-	is the switching hysteresis fraction.
T1	-	is turn-on effective delay time (sec).
T2	-	is turn-off effective delay time (sec).
DC	-	is the computed duty cycle.
A	-	is the computed limit cycle rate (rad/sec).
NDOVER	-	is a deadband overshoot condition check = 0 no deadband overshoot = 1 deadband overshoot
FCT	-	is a factor computed by subroutine OVRF used when second order thrust response is indicated. If FCT is less than or equal to zero iteration on pulse width is not used.

### HISTO

This subroutine sorts and plots a histogram on the line printer from an array of numbers. It must be given maximum and minimum values, the number of values and the increment for each cell of the histogram. The maximum cell count is 94 to fit the line printer. Below each cell the numerical value of the cell range and the count is printed. Asterisks are used to build the histogram.

The call to this subroutine is:

CALL HISTO (X, N, XMAX, XMIN, DX)

X	-	is an array of numbers for the histogram (input).
N	-	is the number of values in the 'X' array (input).
XMAX	-	is maximum value value in 'X' (input).
XMIN	-	is minimum value in 'X' (input).
DX	-	is the histogram cell width (input).

### OVRF

This short subroutine computes a factor for control motor thrust when characterized by an overshoot response.

The call to this subroutine is:

CALL OVRF (T, OR, FAC)

T	-	is given time from zero thrust to first overshoot peak (sec).
OR	-	is given overshoot ratio ( $F_p/F_c$ ).
FAC	-	is computed factor to be used for thrust level on short pulse widths.

### PAGEHD

For output this subroutine ejects a page and prints run number and page number at the top of each page.

The call to this subroutine is:

CALL PAGEHD (NRUN, NPAGE, NLINE)

NRUN	-	is the input run number to be printed.
NPAGE	-	is the input page number to be printed.
NLINE	-	is the returned line number count for the main routine.

### PZC

This function subprogram computes the probability of a parameter falling in a specific range for a Normal or Weibull distribution function. It uses a table lookup of probability for the Normal Distribution function.

The call to this subroutine is:

CALL PZC (XL, XU, AM, AS, WA, WB, WC, LD, M)

XL	-	is input lower limit value.
XU	-	is input upper limit value.
AM	-	is input distribution mean value.
AS	-	is input distribution standard deviation.
WA, WB, WC	-	is input Weibull distribution parameters if LD > 0.
LD	-	is option LD ≤ 0 Normal distribution. LD > 0 Weibull distribution.
M	-	is current or last table lookup indicator.

This subroutine uses the Normal distribution tables in common block 'CZ' entered in Subroutine CHISQ. Probabilities for the Weibull distribution are based on Equation 2-47.

### RANGE

'RANGE' is used for histogram preparation. It computes a desirable cell definition using the range of the data and a desired number of cells. The number of cells will be equal to or greater than that specified depending upon the evenness of the cell width. Acceptable engineering divisions are used in selecting cell starting and ending values. The array must be in ascending order. If it is in descending order it is first rearranged to ascending order.

The call to this subroutine is:

CALL RANGE (X, N, XMAX, XMIN, DX, NDX, ERRTB)

X	-	is an input array of values in ascending or descending order.
N	-	is number of values in 'X' array.
XMAX	-	is calculated upper value of 'X' array.
XMIN	-	is calculated lowest value of 'X' array.
DX	-	is computed cell width for histograms.
NDX	-	is the computed number of cells for the histogram.
ERRTB	-	is an error signal generated.
		= 0 indicates no problems
		= 1 indicates a zero range for the 'X' table

#### RNDX

A pseudo random number generator for a Normal Distribution,  $N(0, 1)$ . It uses as computer supplied uniform random number generator (RANF) to generate a number from zero to one. This is transformed to give the Random Normal Deviate (RXD) from the Normal distribution having zero mean and unity variance. The coding presented in this report also shows an alternate pseudo random number generator which can be used in place of RANF.

The call to this subroutine is:

CALL RNDX (JK)

JK	-	is the number of random normal deviates to be calculated.
----	---	---

The input seed 'K' and the generated random normal deviates 'RXD' are transferred through blank common.

#### RUNGE

This is the basic fourth-order RUNGE-KUTTA integration method which is used in conjunction with CALCU to integrate the trajectory equations.

The call to this subroutine is:

CALL RUNGE (L, I)

L	-	is the control parameter for the Runge-Kutta integration formulae.
I	-	is the counter for the number of passes made in the multi-step process of one integration step. It is set to zero after completion of a complete cycle.

#### TABGEN

In cases where a ballistic (gravity turn) trajectory is flown following booster ignition certain trajectory tables are estimated by this subroutine. It uses a fourth order RUNGE-KUTTA integration of the trajectory equations in subroutines CALCU and RUNGE. It requires initial conditions of flight path angle, dynamic pressure, velocity, predicted attitude error, and drag coefficient. Input tables of thrust and weight are used. After filling tables of dynamic pressure, velocity, altitude and flight path angle, it changes the input pitch attitude error table (TABLE 6) to pitch attitude using the newly calculated flight path angle as the reference attitude.

The call to this subroutine is:

CALL TABGEN (QO, VO, GAMO)

QO                -    is the input initial dynamic pressure (lbs/ft<sup>2</sup>).  
VO                -    is the input initial velocity (ft/sec).  
GAMO              -    is the input initial flight path angle (degrees)

Output data is transferred via labeled common block 'DOUT'. Input data is transferred by common blocks 'DRH', 'DDI', and 'DDY'. This subroutine contains the data table of the logarithm of inverse atmospheric density versus altitude 'RHO' which is contained in common blocks 'DRH'.

#### TBLN

This is a single table lookup subroutine using linear interpolation between points. This subroutine requires separate arrays of abscissas and ordinates. The abscissas must be in ascending order.

The call to this subroutine is:

CALL TBLN (Y, X, T, A, NT, M)

Y                -    is the ordinate to be found.  
X                -    is the given abscissa.  
T                -    is the abscissa table.  
A                -    is the corresponding ordinate table.  
NT               -    is the number of values in each table.  
M                -    is a current locator for the search of the table.  
                 'M' must be greater than zero and less than or equal to  
                 'NT'. M returns the current location found for the  
                 abscissa and should be used for the next lookup of the  
                 same table to reduce the search time.

#### TBLU

This is also a single table lookup. It is based on linear interpolation between points for a single array having alternating values of abscissas and ordinates. The abscissas must be in ascending order.

The call to this subroutine is:

CALL TBLU (NT, Y, X, T, M)

NT               -    number of values in table 'T' including abscissas and  
                 ordinates.  
Y                -    is the ordinate to be found.  
X                -    is the given abscissa.  
T                -    is the table of alternating abscissas and ordinates.  
M                -    is the table locator described under 'TBLN' above.

### THEMIN

'THEMIN' computes the minimum acceleration for which one sided limit cycle motion can occur (Figure 3).

The call to this subroutine is:

CALL THEMIN (THEC, GR, DR, H, T1, T2, THMIN)

THEC	-	is the given control acceleration (rad/sec <sup>2</sup> ).
GR	-	is the rate to displacement gain ratio ( $K_R/K_D$ sec).
DR	-	is the deadband halfwidth (radians).
H	-	is the switching hysteresis fraction.
T1	-	is the turn-on time delay (seconds).
T2	-	is the turn-off time delay (seconds).
THMIN	-	is the computed disturbing angular acceleration at which the deadband will get crossed (rad/sec <sup>2</sup> ).

### WBL

'WBL' is the main subroutine which computes the statistical parameters from an array of numbers. It computes the mean, standard deviation, skewness and kurtosis parameters as well as selected probability levels based on the Normal, Log-Normal and Weibull probability distribution functions. It also estimates a Level of Significance based on the Chi-Squared Goodness of Fit Test.

The call to this subroutine is:

CALL WBL (N, Y, NG, F)

N	-	is the number of values in the sample population.
Y	-	is the sample population array.
NG	-	is the number of cells to be used for the CHI-Squared Goodness of Fit Test.
F	-	is an array of 20 numbers containing the output information.
F(1)	-	is sample mean
F(2)	-	standard deviation
F(3)	-	skewness
F(4)	-	kurtosis
F(5)	-	mean of logarithm of values
F(6)	-	standard deviation of logarithm of values
F(7)	-	skewness of logarithm of values
F(8)	-	kurtosis of logarithm of values
F(9)	-	0.995 probability level, 0.95 confidence level, for Normal Distribution
F(10)	-	predicted 0.995 probability level, 0.95 confidence level, based on Log-Normal distribution
F(11)	-	'a' parameter for Weibull Distribution
F(12)	-	'b' parameter for Weibull Distribution
F(13)	-	'c' parameter for Weibull Distribution
F(14)	-	0.5 probability level for Weibull Distribution
F(15)	-	0.990 probability level for Weibull Distribution
F(16)	-	0.995 probability level for Weibull Distribution
F(17)	-	0.999 probability level for Weibull Distribution
F(18)	-	level of significance for Normal Distribution
F(19)	-	level of significance for Log-Normal Distribution
F(20)	-	level of significance for Weibull Distribution

### 3.4 Input Data Description

Input data is in fixed field format and includes fixed point, hollerith and floating point fields. Figure 7 presents a sample run input listing. Basic groups of input include the following:

- 1) one card of fixed point numbers including all of the run options, run number, number of random samples and number of boost phase integration steps,
- 2) two cards of Hollerith data describing the run for output heading,
- 3) initial random sequence integer for the pseudo random number generator,
- 4) moment of inertia and center of mass table,
- 5) list of single values of vehicle, mission and control system constants,
- 6) list of statistical means and standard deviations of random variables for the boost phase,
- 7) optional separate coast control variables,
- 8) tables of vehicle, trajectory time histories and wind versus altitude tables,
- 9) Optional vehicle and trajectory inputs replacing Group 8

#### 3.4.1 Group 1 Input (Input Options)

The first card of input includes eleven fixed point constants in fields of five, right justified, starting in columns 1 through 5. These are:

<u>Card Column</u>	<u>FORTTRAN Variable</u>	<u>Description</u>
1-5	NRUN	An arbitrary run number
6-10	IT	Number of random cases to be computed by the Monte Carlo procedure (current dimensions limit this to 1000 samples)
15	IO(1)	Output print option 1 Gives output information for each sample and the statistical distribution information 2 Gives only the statistical distribution information
20	IO(2)	2 Assumes the coast control and boost controls are the same 3 Coast control system uses different input than boost system (this requires additional input under Group 7)

<u>Card Column</u>	<u>FORTTRAN Variable</u>	<u>Description</u>
25	I0(3)	1 Calculate boost fuel and coast time 2 Calculate boost, coast and total fuel (If I0(2) = 3; retro time is computed based on input total fuel available in Group 5)
30	I0(4)	1 Deletes control system pitch and yaw filter delay time in coast after time specified in Group 5 input 2 Control system filter delay used in boost and coast
34-35	I0(5)	Number of integration steps (up to 50) to be used in boost fuel consumption during web time (web time is specified in Group 5 data)
39-40	I0(6)	Number of integration steps to be used during booster motor tail off between web time and burnout time specified in Group 5 data
45	I0(7)	Separate coast control logic if I0(2) = 3, 0 Coast roll motors used for yaw and roll 1 Coast pitch and yaw motors are the same
50	I0(8)	0 Input all trajectory tables in Group 8 1 Input Group 9 data instead of Group 8
55	I0(9)	0 Print histograms of fuel consumption 1 No histogram output

#### 3.4.2 Group 2 Title

Group 2 includes two cards of Hollerith arbitrary data for the user to describe the run. It includes only the first seventy two (72) columns on each card. This information is written on the first page of output of the run.

#### 3.4.3 Group 3 Initial Random Number Seed

The fourth card of input is an integer number for the start of the pseudo-random number generator. It is located in the first eighteen (18) columns on the card and is right justified. On IBM machines having seven digit accuracy this should be changed to a seven digit integer (eg. 1234567) and a Format change would be required. This also requires the optional coding in the subroutine RNDX shown in the FORTRAN listing.



#### 3.4.4 Group 4 Mass Properties

This group provides the transverse moment of inertia and center of mass station versus fraction of booster propellant consumed. It uses three points (0, 0.5 and 1.0) of propellant consumed to fit the data to a second order polynomial. The nine values are stored in array TABLE 1. Data is entered three to a card in three fields of 10 columns as follows,

Col. 1-10	11-20	21-30	values at
0.0	Iy (Slug-Ft <sup>2</sup> )	X <sub>cg</sub> (Sta. in.)	ignition
0.5	Iy	X <sub>cg</sub>	50%
1.0	Iy	X <sub>cg</sub>	burnout

#### 3.4.5 Group 5 Single Constants

This group used on all runs consists of single valued constants. There are twenty-one cards in this group. Each card has a single value located in the first fifteen columns (Format E15.5). The first sixteen values are stored in the "A" array. These start with card eight.

<u>Card No.</u>	<u>FORTTRAN Variable</u>	<u>Symbol</u>	<u>Units</u>	<u>Description</u>
8	A (1)	N	--	number of samples for correlating thrust misalignment initial value with slope
9	A (2)	$\rho_{\epsilon_{\tau_0} \dot{\epsilon}_\tau}$		correlation coefficient for pitch thrust misalignment
10	A (3)	$\rho_{\epsilon_{\tau_0} \dot{\epsilon}_\tau}$		correlation coefficient for yaw thrust misalignment
11	A (4)	X <sub>C</sub>	inches	body station of control motors
12	A (5)	Z <sub>C</sub>	inches	radial location of pitch and yaw control motors
13	A (6)	X <sub>T</sub>	inches	body station of booster nozzle throat or action point of thrust misalignment
14	A (7)	R <sub>C</sub>	inches	roll control motor moment arm from centerline
15	A (8)	cos $\lambda$	--	cosine of the pitch and yaw control motors forward cant angle

<u>Card No.</u>	<u>FORTTRAN Variable</u>	<u>Symbol</u>	<u>Units</u>	<u>Description</u>
16	A (9)	$\sin \lambda$	--	sine of the pitch and yaw control motor forward cant angle
17	A (10)	$t_f$	seconds	time from ignition during which the filter delay is operating with the control system
18	A (11)	$t_{\text{coast}}$	seconds	coast time from burnout
19	A (12)	$W_f$	pounds	total control fuel available (used to compute retro time or coast time with appropriate options)
20	A (13)	$t_{\text{web}}$	seconds	booster web time or action time from ignition
21	A (14)	$t_{\text{bo}}$	seconds	booster burnout time after ignition
22	A (15)	$W_{\text{bo}}$	pounds	vehicle weight at booster burnout
23	A (16)	$I_x$	slug-ft <sup>2</sup>	vehicle roll moment of inertia at burnout
24	CNAS	$C_{N\alpha}$	ft <sup>2</sup> /rad	aerodynamic normal force coefficient slope
25	XCP	$X_{\text{cp}}$	inches	vehicle aerodynamic center of pressure station
26	GAME1	$\gamma_{e1}$	degrees	standard deviation of initial flight path angle
27	ZEI	$\zeta_{e1}$	degrees	standard deviation of initial azimuth
28	QFRAC	--	--	standard deviation of dynamic pressure ratio ( $Q_{\text{actual}}/Q_{\text{nominal}}$ )

### 3.4.6 Group 6 Random Variables

This group includes the mean and standard deviation of related boost system random variables. These are read in two values per card (format 2E15.5). This group starts with card 29 and continues through card 59.

<u>Card No.</u>	<u>FORTTRAN Variable</u>	<u>Symbol</u>	<u>Units</u>	<u>Description</u>
29	ORM,ORS	Fp/Fc	--	boost pitch and yaw, control motor overshoot ratio mean and standard deviation for second order thrust response (Fig. 4) (if ORM 1.0, constant square wave thrust is assumed)
30	TPM,TPS	tp	seconds	pitch and yaw control motor time to peak overshoot thrust mean and standard deviation (Ignored if ORM = 1)
31	T2FM,TRFS	-	seconds	effective turn off delay time due to vehicle flexibility, mean and standard deviation (not used when filter is included)
32	B(1), B(2)	$\epsilon_{r_{op}}$	degrees	initial value of pitch thrust misalignment (mean and standard deviation)
33	B(3), B(4)	$\epsilon_{r_{oy}}$	degrees	initial value of yaw thrust misalignment (mean and standard deviation)
34	B(5), B(6)	$\dot{\epsilon}_{r_p}$	deg/sec	mean and standard deviation of time rate of change of pitch thrust misalignment
35	B(2), B(8)	$\dot{\epsilon}_{r_y}$	deg/sec	mean and standard deviation of time rate of change of yaw thrust misalignment
36	B(9), B(10)	I <sub>sp</sub>	seconds	boost control motor specific impulse mean and standard deviation
37	B(11), B(12)	$\dot{\theta}_0$	deg/sec	mean and standard deviation of initial pitch rate
38	B(13), B(14)	$\theta_{e_0}$	degrees	mean and standard deviation of initial pitch attitude error

<u>Card No.</u>	<u>FORTTRAN Variable</u>	<u>Symbol</u>	<u>Units</u>	<u>Description</u>
39	B(15), B(16)	$\dot{\psi}_0$	deg/sec	mean and standard deviation of initial yaw rate
40	B(17), B(18)	$\psi_{e0}$	degrees	mean and standard deviation of initial yaw attitude error
41	B(19), B(20)	RTI	ft-lb-sec	booster induced roll angular impulse mean and standard deviation
42	B(21), B(22)	$\epsilon_{JET}$	degrees	mean and standard deviation of pitch and yaw control motor misalignment contributing to roll moment
43	B(23), B(24)	$\zeta_W$	degrees	mean and standard deviation of wind direction azimuth
44	B(25), B(26)	$\Delta I_y$ $\Delta X_{cg}$	slug-ft <sup>2</sup> inches	standard deviation of transverse moment of inertia and standard deviation of center of mass station in inches
45	C(1), C(2)	$\Delta t_f$	seconds	pitch and yaw filter delay time mean and standard deviation
46	C(3), C(4)	$t_{rg}$	seconds	mean and standard deviation of pitch and yaw gyro time delay
47	C(5), C(6)	$t_{1m}$	seconds	mean and standard deviation of pitch and yaw control motor turn-on delay time
48	C(7), C(8)	$t_{2m}$	seconds	mean and standard deviation of pitch and yaw control motor turn-off delay time
49	C(9), C(10)	$K_R/K_D$	seconds	boost pitch and yaw control system gain ratio mean and standard deviation
50	C(11), C(12)	$d_b$	degrees	boost pitch and yaw control deadband halfwidth mean and standard deviation
51	C(13), C(14)	H	--	mean and standard deviation of boost pitch and yaw control hysteresis fraction ( $1-d_{off}/d_{on}$ )
52	C(15), C(16)	$F_c$	pounds	boost pitch and yaw control motor thrust mean and standard deviation

<u>Card No.</u>	<u>FORTTRAN Variable</u>	<u>Symbol</u>	<u>Units</u>	<u>Description</u>
53	C(17), C(18)	$t_{RG}$	seconds	roll rate gyro delay time mean and standard deviation
54	C(19), C(20)	$t_{1M}$	seconds	boost roll motor turn-on delay time mean and standard deviation
55	C(21), C(22)	$t_{2M}$	seconds	boost roll motor turn-off delay time mean and standard deviation
56	C(23), C(24)	$K_R/K_D$	seconds	boost roll control gain ratio mean and standard deviation
57	C(25), C(26)	$d_b$	degrees	boost roll deadband halfwidth mean and standard deviation
58	C(27), C(28)	H	--	boost roll switching hysteresis (1 - $d_{off}/d_{on}$ ) mean and standard deviation
59	C(29), C(30)	$F_c$	pounds	boost roll control motor thrust mean and standard deviation

#### 3.4.7 Group 7 Separate Coast System Variables (IO(2) = 3 Only)

This group is an optional input if a separately defined coast control system is used. This information must be input if IO(2) = 3 on the first card. This allows separate control motors, gains, time delays and a retro function during coast using the canted forward boost control motors. The first four cards are input one value per card with format E15.5. They are:

<u>Card No.</u>	<u>FORTTRAN Variable</u>	<u>Symbol</u>	<u>Units</u>	<u>Description</u>
60	PTRC	$\Delta \dot{\theta}_c$	deg/sec	total pitch program rate changes during coast
61	YTRC	$\Delta \dot{\psi}_c$	deg/sec	total yaw program rate change during coast
62	TRETRO	$t_{retro}$	seconds	retro time required following coast with four boost pitch and yaw control motors

<u>Card No.</u>	<u>FORTTRAN Variable</u>	<u>Symbol</u>	<u>Units</u>	<u>Description</u>
63	RETRSI	$I_{sp}$	seconds	retro motor specific impulse

In addition to these four cards, there are nine (9) additional cards of statistical control system values having two values per card (format 2E15.5). These are:

<u>Card No.</u>	<u>FORTTRAN Variable</u>	<u>Symbol</u>	<u>Units</u>	<u>Description</u>
64	D(1), D(2)	$d_c$	degrees	coast system pitch and yaw deadband halfwidth, mean and standard deviation
65	D(3), D(4)	$F_c$	pounds	coast pitch control motor force, mean and standard deviation
66	D(5), D(6)	$t_{1M}$	seconds	coast pitch motor turn-on delay time, mean and standard deviation
67	D(7), D(8)	$t_{2M}$	seconds	coast pitch motor turn-off delay time, mean and standard deviation
68	D(9), D(10)	$d_c$	degrees	coast roll deadband halfwidth, mean and standard deviation
69	D(11), D(12)	$F_c$	pounds	coast roll motor thrust, mean and standard deviation
70	D(13), D(14)	$t_{1M}$	seconds	coast roll motor turn-on delay time, mean and standard deviation
71	D(15), D(16)	$t_{2M}$	seconds	coast roll motor turn-off delay time, mean and standard deviation
72	D(17), D(18)	$I_{sp}$	seconds	coast control specific impulse, mean and standard deviation

#### 3.4.8 Group 8 Trajectory Tables IO(8) = 0

This group concludes the input data stream for a run. It includes tables of time and altitude histories. If IO(8) = 1 certain tables are deleted as described in Group 9 in the following paragraph. Each table is input in the same format. Preceding each table a card having the integer number of values in the table is located in columns 1 through 5, right justified (Format I5).

The values are entered alternating abscissas and ordinates in fields of ten columns. These are entered six (6) per card until the table is completed. Figure 7 is the input for the sample problem which shows this format. The format for the whole table is (I5/(6F10.3)). A description of the tables and their order is:

<u>TABLE NAME</u>	<u>ORDINATE</u>	<u>UNITS</u>	<u>ABSCISSA</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
TABLE 1	Q	lbs/ft <sup>2</sup>	t	sec	dynamic pressure versus time after ignition
TABLE 2	T	lbs	t	sec	booster nominal thrust versus time after ignition
TABLE 3	W <sub>p</sub>	lbs	t	sec	booster propellant weight remaining versus time after ignition
TABLE 4	$\theta_c$	deg	t	sec	pitch program attitude from local horizontal versus time after ignition
TABLE 5	V	ft/sec	t	sec	nominal velocity versus time after ignition
TABLE 6	$\gamma_{PR}$	degrees	t	sec	flight path angle from local horizontal versus time after ignition
TABLE 7	$\zeta_{PR}$	degrees	t	sec	nominal azimuth versus time after ignition
TABLE 8	$\beta_{NOM}$	degrees	t	sec	nominal angle of sideslip versus time after ignition on an undisturbed trajectory
TABLE 9	V <sub>W<math>\mu</math></sub>	ft/sec	h	ft	mean value of wind velocity versus altitude above sea level
TABLE 10	V <sub>W<math>\sigma</math></sub>	ft/sec	h	ft	standard deviation of wind velocity versus altitude above sea level
TABLE 11	h	feet	t	sec	altitude versus time after ignition

Each of the above tables is limited to ninety (90) values which is a maximum of forty-five (45) pairs of abscissas and ordinates.

### 3.4.9 Group 9 Trajectory Tables IO(8) = 1

For parametric studies the option to generate nominal trajectory parameters becomes useful. This option generates a gravity turn trajectory from other input data. With this option Group 9 data replaces Group 8 data. Figure 8 presents a sample input for the case. The first card includes four variables read in four fields of ten columns (format 8F10.3). These variables are:

<u>FORTTRAN</u> <u>VARIABLE</u>	<u>SYMBOL</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
QO	$Q_0$	lbs/ft <sup>2</sup>	nominal dynamic pressure at ignition
VO	$V_0$	ft/sec	nominal velocity at ignition
GAMO	$\gamma_0$	degrees	nominal flight path angle at stage ignition
CDS	$C_{DS}$	ft <sup>2</sup>	aerodynamic drag coefficient times reference area

Following this card seven tables are entered. Each table is preceded by a card containing the integer number of values in the table in a field of five (5) right justified (format I5). Following this card the table is entered in floating point numbers in fields of ten (10) columns, six (6) values per card. The format is (6F10.3). The order and description of these tables are as follows:

<u>TABLE NAME</u>	<u>ORDINATE</u>	<u>UNITS</u>	<u>ABSCISSA</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
Table 2	T	lbs	t	sec	booster nominal thrust versus time after ignition
Table 3	W	lbs	t	sec	booster nominal thrust versus time after ignition
Table 4	$\theta_C - \gamma_{PR}$	degrees	t	sec	difference between nominal pitch attitude and flight path angle versus time after ignition
Table 7	$\zeta_{PR}$	degrees	t	sec	predicted azimuth time history
Table 8	$\beta_{NOM}$	degrees	t	sec	nominal angle of sideslip versus time after ignition
Table 9	$V_{W\mu}$	ft/sec	h	feet	mean value of wind, velocity versus altitude
Table 10	$V_{W\sigma}$	ft/sec	h	feet	standard deviation of wind velocity versus altitude



### 3.5 Output Description

All output is on a line printer. There are several options for the output which are selected by the run options presented in paragraph 3.4.1.

There are five basic parts to the output, two of which can be deleted by input option. These include:

- 1) printout of selected parameters from each random sample ( $IO(1) = 1$ ), can be deleted if ( $IO(1) = 2$ ),
- 2) printout of all fuel consumption values arranged in ascending order with associated sample population probability level (always output),
- 3) sample distribution statistical parameters, final random number generator seed and number of samples having deadband overshoot occurrences,
- 4) summary statistics and level of significance for Normal, Log-Normal and Weibull Distribution functions,
- 5) histograms of the fuel consumption ( $IO(9) = 0$ ), can be omitted if ( $IO(9) = 1$ )

Details of these parts of the output are presented in the following subparagraphs.

#### 3.5.1 Individual Sample Parameters

If the input option ( $IO(1) = 1$ ), two lines of parameters from each Monte Carlo random sample case are printed out after each case. This option results in a relatively large amount of printout. A typical page of output of these parameters is presented in Figure 9. A description of each in the order of output is:

<u>OUTPUT NAME</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
SMPL	--	an integer sequence of the Monte Carlo case number
CAPT IMP	lb-sec	staging "capture" transient impulse
ROLL TORQIMP	lb-sec	roll control motor impulse due to rocket booster induced roll torque (RTI)
BOOSTIMP	lb-sec	total control impulse required during boost phase
T(WEB)	sec	booster web time
T(TO)	sec	booster tail off time

<u>OUTPUT NAME</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
BOOST FUEL	lbs ,	control fuel consumption during boost
ISP	sec	control fuel specific impulse
CST FUEL	lbs	control fuel consumption during coast (not including retro fuel)
FLOW RATE	lbs/sec	coast fuel consumption flow rate with boost system - filter in
DB RED TORQ FUEL	lbs	fuel consumption required for deadband reduction transient and pitch program rate changes during coast
FLOW RATE COAST	lbs/sec	fuel flow rate during coast
RETRO TIME	sec	retro time achieved with remaining fuel consumption after coast
NO. OF DB OVERSHOOTS BOOST P-Y ROLL CST P-Y		number of times deadband overshoot occured during boost in pitch or yaw, in the roll channel, and during coast in pitch or yaw
TOTAL FUEL	lbs	total fuel consumption including boost, coast and retro

When the coast time option is used, (IO(3) = 1), (TOTAL FUEL) and (COAST FUEL) is deleted and (COAST TIME) is output in seconds.

### 3.5.2 Discrete Probability Levels

Fuel consumption in boost and coast, total fuel consumption and under some options retro time or coast time is printed versus probability of occurrence after being arranged in ascending order. A sample output is presented in Figure 10.

### 3.5.3 Sample Distribution and Final Seed

This page of output is presented in Figure 11. It includes the computed mean, standard deviation and estimated 99.5 percent probability with 95 percent confidence level of fuel consumption.

The last value calculated of the pseudo random number generator seed is output. This can be used as a starting value if an additional run is to be made to increase the sample size with the least risk of repeating parts of the sequence generated in the previous run.

The total number of cases having exceeded the deadband overshoot criteria at least once is also output on this page. Differentiation between boost and coast phases is made as well as roll axes during boost. The deadband overshoot criteria is an indicator of a very poorly designed on-off control system since it approaches a 100 percent duty cycle.

#### 3.5.4 Summary Statistics and Level of Significance

A page of statistical information is output for comparison of the sample population with known distributions. Figure 12 presents a typical example. Sample population mean, standard deviation, skewness and kurtosis parameters are output under Normal Distribution. The estimated upper 95 percent confidence level at the 99.5 percent probability level is based on a prediction if the distribution were truly Gaussian (which is usually not the case). Level of Significance is computed based on the Chi-Squared Goodness of Fit Test. The level of significance is output for each of the distributions. A higher level of significance generally indicates a better fit. However, histogram output should also be considered in the statistical analysis.

Under the Log-Normal Distribution the sample distribution parameters for the natural logarithm of the fuel consumption is shown. The fuel consumption at the upper 95 percent confidence level at 99.5 percent probability level predicted by the Log-Normal distribution is also shown in pounds. Note that the parameters are expressed as the logarithm but the 99.5 percent level is not the logarithm. Level of significance is also presented from the Chi-Squared Goodness of Fit Test.

Weibull Distribution parameters (a, b, c) are presented which are based on the sample population. Values of fuel consumption at several selected probability levels as predicted by the fit to a Weibull Distribution are also output. Level of Significance from a Chi-Squared Goodness of Fit Test to the ideal Weibull Distribution having these parameters is also output.

#### 3.5.5 Histograms

Histograms of the sample populations of fuel consumption and retro times are an optional output. Samples of this output are presented in Figure 13. Each output histogram includes:

- . Identification
- . Total number of samples
- . Minimum and maximum values
- . Number of values in each cell printed numerically below each cell
- . Numerical value of starting and end points of each cell printed under each cell
- . Graphical display of each cell by number of stars or asterisks rising from the base

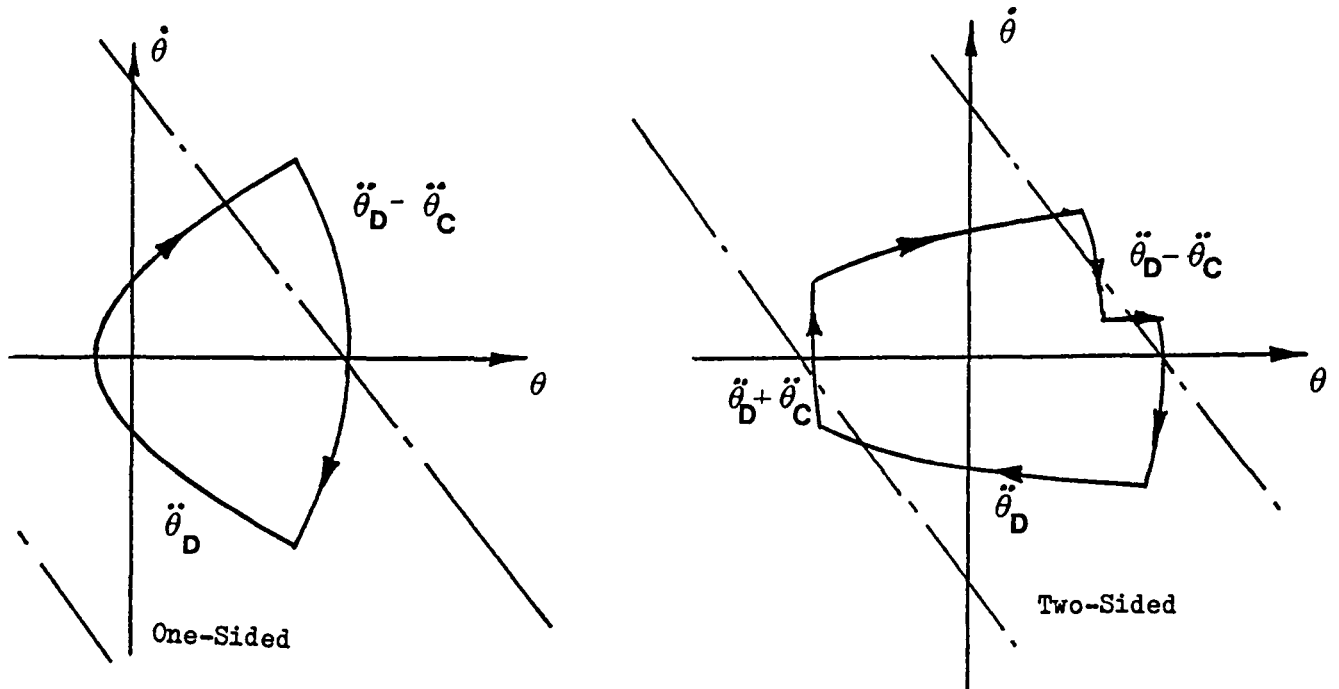
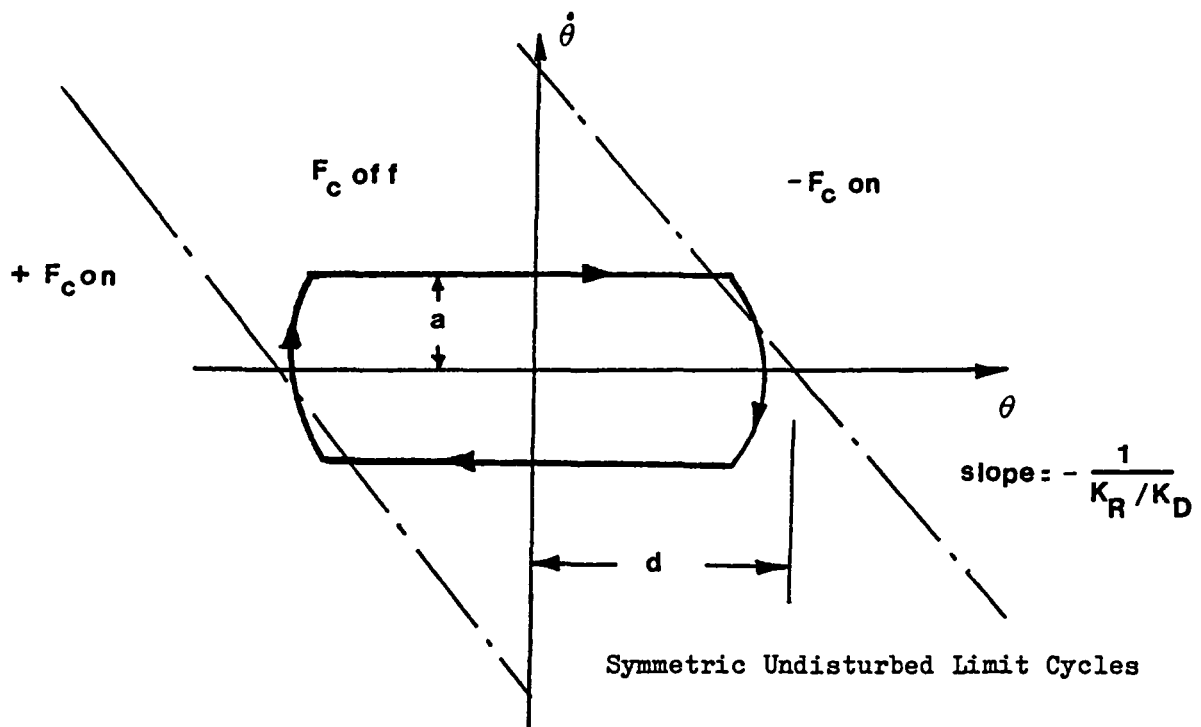
Maximum number of samples in a cell is 94 for display purposes. If a cell is completely filled the actual height can be obtained from the number printed at the base of the cell. The number of cells is automatically set at 30 or more over the range of data. In order to select aesthetically pleasing cell divisions the number of cells will vary somewhat and occasionally spill over more than a single page of output.

## REFERENCES

### 4.0 REFERENCES

- (1) Glazier, M. N. and Knauber, R. N., "Scout Upper Stage Control Fuel Consumption Analysis - Revision C", Vought Corp. Report No. 23.256, 26 October 1971.
- (2) Lindgren, B. W. and McElrath, G. W., "Introduction to Probability and Statistics." The Macmillan Company, New York, second printing 1960.

Figure 1  
Control Phase Plane - Limit Cycles



Disturbed Limit Cycles

Figure 2  
Trajectory and Angle Definitions

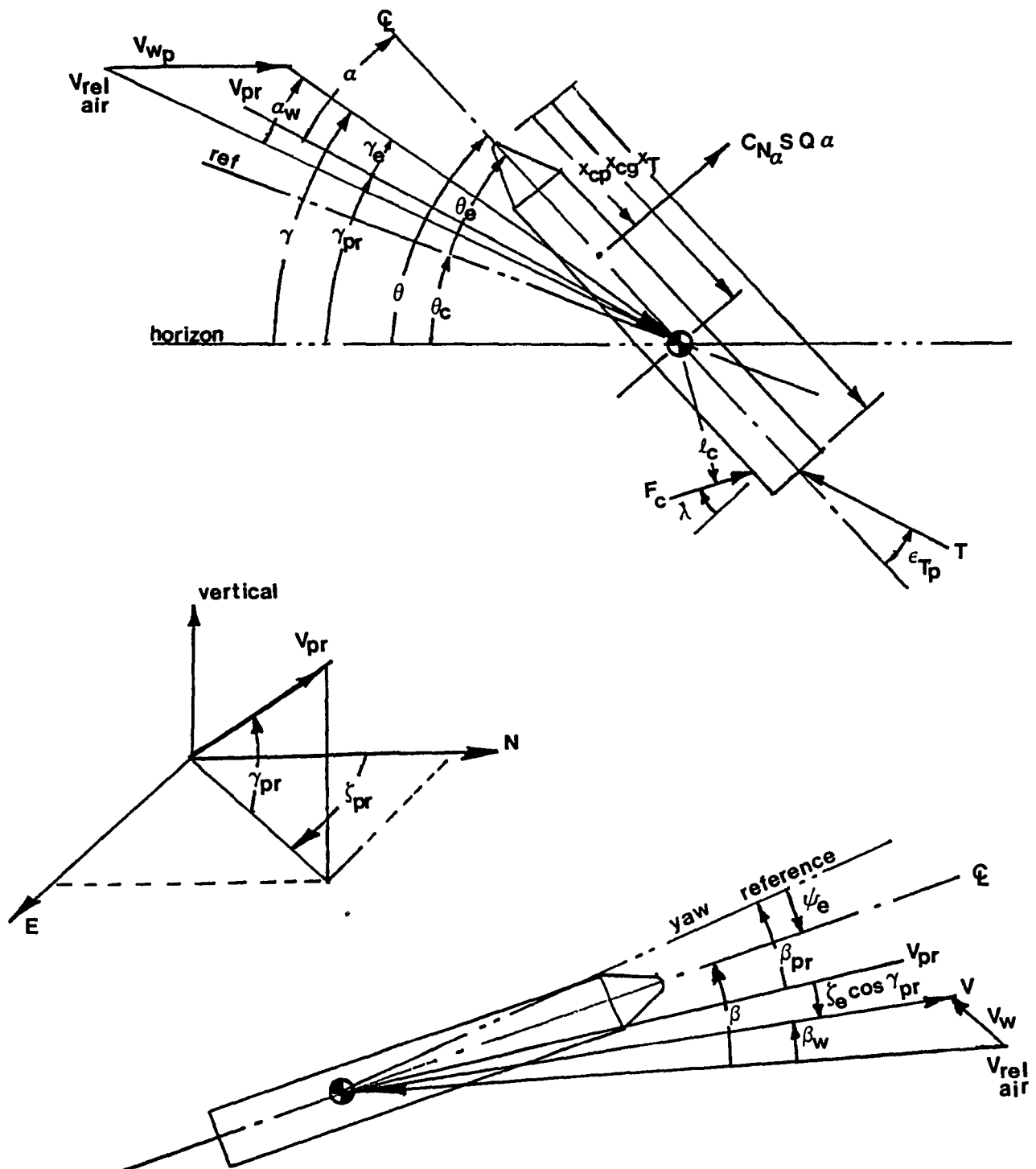
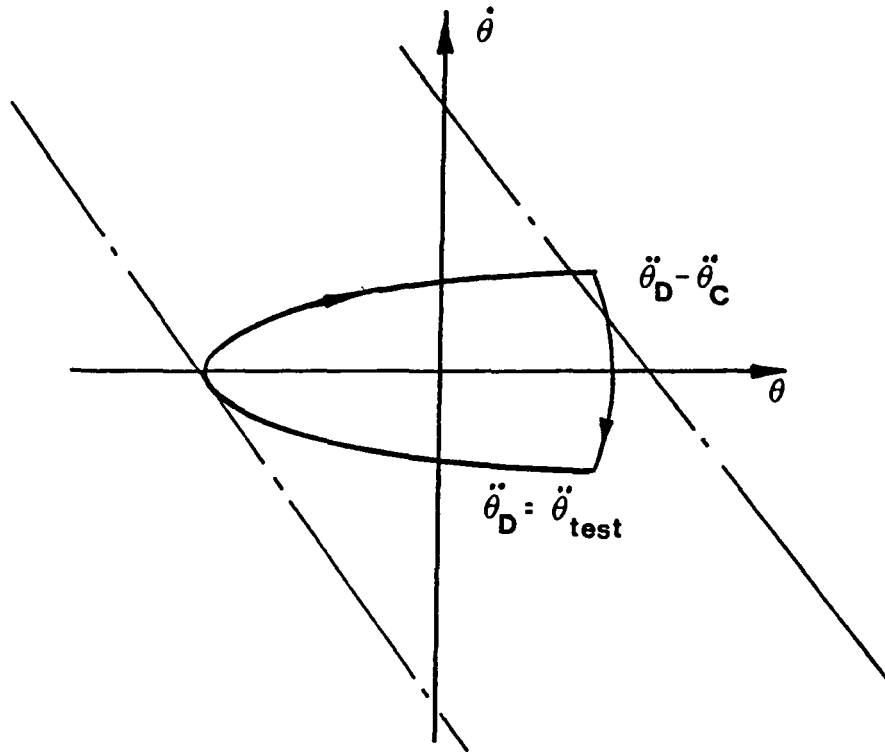


Figure 3  
Minimum Acceleration for Deadband Crossing



$$\ddot{\theta}_{\text{test}} = \left| -\frac{E}{2D} \pm \sqrt{\left(\frac{E}{2D}\right)^2 + \frac{F}{D}} \right|$$

$$D = B - (K_R/K_D - T_1) \left( \frac{B-C}{A} \right) - 0.5 (K_R/K_D)^2 - 0.5 \left( \frac{B-C}{A} \right)^2$$

$$E = -2d - (K_R/K_D - T_1) \left( dH - C\ddot{\theta}_c \right) / A - C \left( \frac{B-C}{A^2} \right) \ddot{\theta}_c$$

$$F = \frac{1}{A^2} \left[ 0.5 (dH + C\ddot{\theta}_c)^2 + dH (B-C) \right]$$

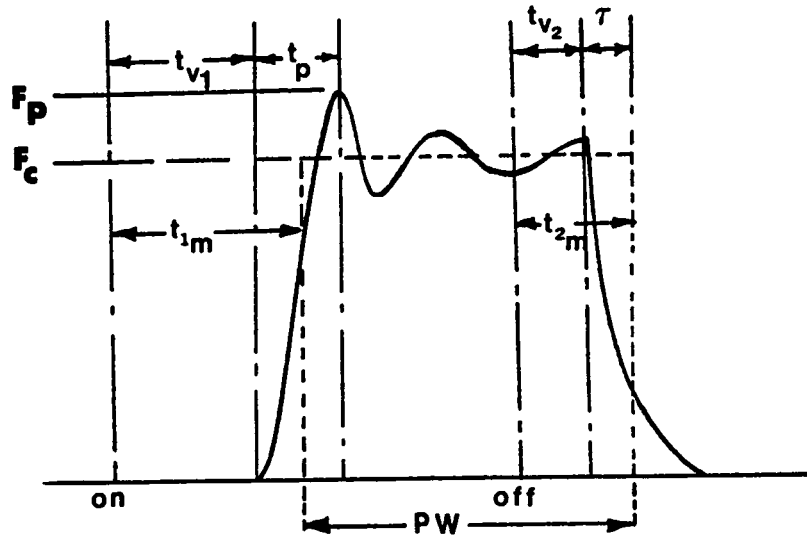
$$A = 2K_R/K_D - T_1 - T_2$$

$$B = K_R/K_D T_1 - T_1^2/2$$

$$C = K_R/K_D T_2 - T_2^2/2$$



Figure 4  
Control Motor Thrust Responses



$$t_{1m} = t_{v1} + t_p \left( 1 - \nu/2 \right) / 2$$

$$\nu = \tan^{-1} \left[ \frac{\pi}{\ln \left( \frac{1}{F_p/F_c - 1} \right)} \right]$$

Figure 5  
General Flow Chart of MAIN Routine

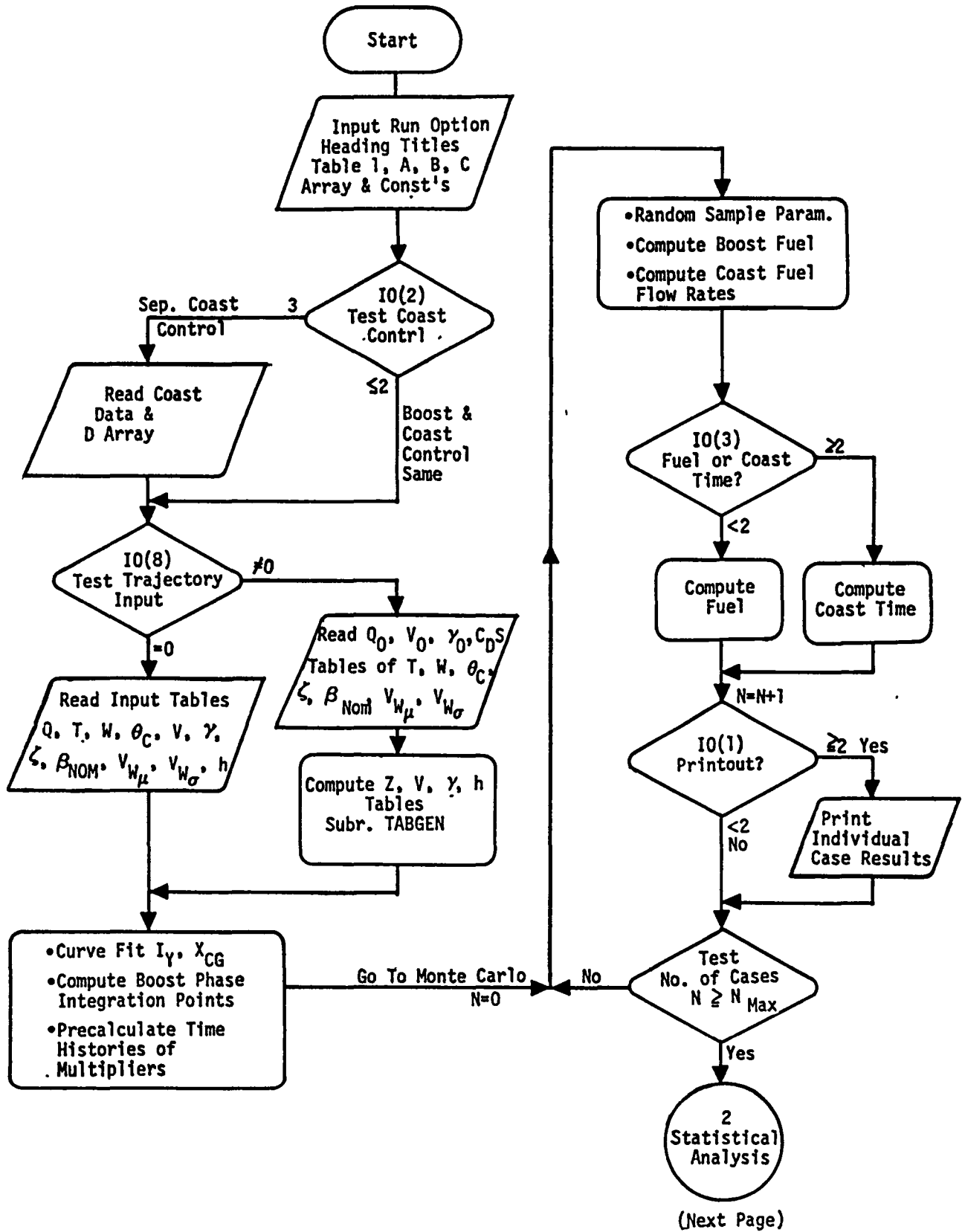


Figure 5 (Cont.)  
General Flow Chart of MAIN Routine

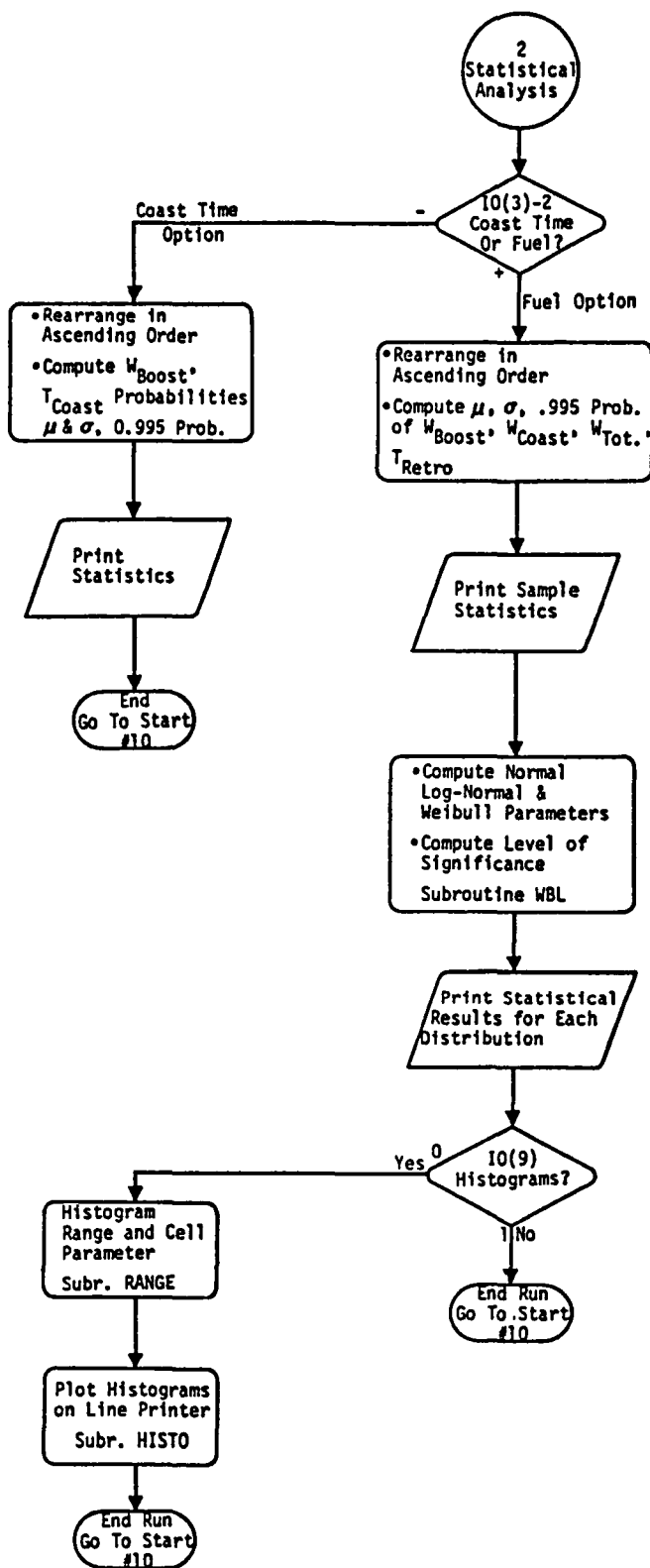


FIGURE 6

## Program Subroutines and Common Interaction Map Subroutines

	ALTI	ASCEND	CALCU	CHISQ	CYCLE	HISTO	OVRF	PAGEHD	PZC	RANGE	RNDX	RUNGE	TABGEN	TBLN	TBLU	THEMIN	WBL
MAIN		X			X	X	X	X		X	X		X		X	X	X
ALTI															X		
ASCEND																	
CALCU															X		
CHISQ									X					X			
CYCLE																	
HISTO																	
OVRF																	
PAGEHD																	
PZC														X			
RANGE																	
RNDX																	
RUNGE																	
TABGEN	X		X									X					
TBLN																	
TBLU																	
THEMIN																	
WBL				X											X		

BLANK	DOUT	DDT	DRH	DDI	DDY	CZ
X	X	X				
			X			
			X	X	X	
						X
						X
X						
					X	
	X		X	X	X	

Figure 7  
Sample Problem Input IO(8) = 0

1	499	2	3	2	1	12	4	1	0	0		
SAMPLE PROBLEM SCOUT SECOND STAGE, FUEL OPTION, FILTER OUT IN												
COAST, SEPARATE COAST CONTROL, NO YAW-ROLL MIXING IO(8)=0												
625699253066457											INITIAL RANDOM SEQ NO RANF	
	0.	49241.45		282.07							IYY AND XCG @IGNITION (SLUG-	
	0.5	41574.21		258.47							@50% PROP FT**2)	
	1.0	27991.96		206.73							@BURNOUT	
		19.									NO. OF SAMPLES FOR CORR COEFF	
		-0.573									CORR COEFF PITCH	
		-0.756									CORR COEFF YAW	
		467.76									CONTROL MOTOR STATION	
		14.93									CONTROL MOTOR LAT. LOC. (IN.)	
		448.51									BOOSTER NOZZLE THROAT STATION	
		16.89									ROLL CONTROL MOTOR ARM (IN.)	
		1.									COS OF CANT ANGLE (NO CANT)	
		0.									SIN OF CANT ANGLE (NO CANT)	
		42.32									FILTER IN TIME (SEC)	
		34.92									COAST TIME (SEC)	
		167.									CONTROL FUEL (LB)	
		35.86									BOOSTER WEB TIME (SEC)	
		39.32									BOOSTER BURNOUT TIME (SEC)	
		6968.26									WEIGHT B/O (LB)	
		205.40									IXX B/O (SLUG-FT**2)	
		30.32									CNAS FT2/RAD	
		134.2									XCP STATION	
		0.30									FLIGHT PATH ERROR (DEG)	SIGMA
		0.38									AZIMUTH ERROR (DEG)	SIGMA
		0.12									DYN.PRESS.RATIO(Q OVER QNOM)	SIGMA
		1.25		0.080							PITCH/YAW MOTOR OVERSHOOT RATIO	MEAN,SIGM
		0.019		0.0047							PITCH/YAW MOTOR TIME TO PEAK (SEC)	MEAN,SIGM
		0.012		0.001							T2 FLEX FILTER OUT COAST (SEC)	MEAN,SIGM
		0.0816		0.0271							INITIAL ET PITCH (DEG)	MEAN,SIGM
		0.0098		0.0239							INITIAL ET YAW (DEG)	MEAN,SIGM
		-0.000193		0.000753							SLOPE OF ET PITCH (DEG/SEC)	MEAN,SIGM

FIGURE 7 (Continued)  
Sample Problem Input IO(8)=0

-0.000302	0.000830	SLOPE OF ET YAW (DEG/SEC)	MEAN,SIGM
125.	0.	BOOST CONTROL ISP (SEC)	MEAN,SIGM
-0.098	0.326	INITIAL PITCH RATE (DEG/SEC)	MEAN,SIGM
0.292	0.340	INITIAL PITCH ERROR (DEG)	MEAN,SIGM
0.085	0.197	INITIAL YAW RATE (DEG/SEC)	MEAN,SIGM
0.0105	0.243	INITIAL YAW ERROR (DEG)	MEAN,SIGM
0.	0.	BOOSTER ROLL IMPULSE (FT-LB-SEC)	MEAN,SIGM
0.	0.3817	PITCH/YAW JET MISALIGNMENT (DEG)	MEAN,SIGM
259.0	20.0	WIND AZIMUTH (DEG)	MEAN,SIGM
0.0166	0.0033	IYY AND XCG STANDARD DEVIATION	SIGMA,SIGM
0.	5.	PITCH STATIC UNBALANCE (FT-LB)	MEAN,SIGM
0.	5.	YAW STATIC UNBALANCE (FT-LB)	MEAN,SIGM
0.0459	0.0034	FILTER DELAY TIME (SEC)	MEAN,SIGM
0.0093	0.0017	PITCH /YAW GYRO DELAY TIME (SEC)	MEAN,SIGM
0.0715	0.0088	PITCH/YAW MOTOR T1 (SEC)	MEAN,SIGM
0.0355	0.0052	PITCH/YAW MOTOR T2 (SEC)	MEAN,SIGM
0.5	0.01667	KR/KD (SEC)	MEAN,SIGM
0.802	0.0267	BOOST PITCH/YAW DEADBANDS (DEG)	MEAN,SIGM
0.035	0.0167	BOOST PITCH/YAW HYSTERESIS (FRACTION)	MEAN,SIGM
517.3	14.5	BOOST PITCH YAW CONTROL FORCE (LB)	MEAN,SIGM
0.0069	0.0008	ROLL RATE GYRO DELAY (SEC)	MEAN,SIGM
0.0251	0.0048	BOOST ROLL MOTOR T1 (SEC)	MEAN,SIGM
0.0162	0.0030	BOOST ROLL MOTOR T2 (SEC)	MEAN,SIGM
0.45	0.015	ROLL GAIN RATIO KR/KD (SEC)	MEAN,SIGM
1.432	0.0478	BOOST ROLL DEADBAND (DEG)	MEAN,SIGM
0.035	0.0167	ROLL HYSTERESIS (FRACTION)	MEAN,SIGM
45.45	1.68	BOOST ROLL MOTOR FORCE (LB)	MEAN,SIGM
0.45		PITCH PROGRAM RATE CHANGE (DEG/SEC)	
0.		YAW PROGRAM RATE CHANGE (DEG/SEC)	
0.		RETRO TIME (SEC)	
134.0		RETRO ISP (SEC)MUST BE NON-ZERO	
0.785	0.0267	PITCH YAW COAST DEADBANDS (DEG)	MEAN,SIGM
517.3	14.5	COAST PITCH MOTOR THRUST (LB)	MEAN,SIGM
0.0715	0.0088	COAST PITCH MOTOR T1 (SEC)	MEAN,SIGM

FIGURE 7 (Continued)  
Sample Problem Input IO(8)=0

	0.0355	0.0052	COAST PITCH MOTOR T2 (SEC)			MEAN,SIG
	1.432	0.0478	COAST ROLL DEADBAND (DEG)			MEAN,SIG
	45.45	1.68	COAST ROLL MOTOR THRUST (LB)			MEAN,SIG
	0.0251	0.0048	ROLL MOTOR T1 (SEC)			MEAN,SIG
	0.0162	0.0030	ROLL MOTOR T2 (SEC)			MEAN,SIG
	125.	0.	COAST ISP (SEC)			MEAN,SIG
20	NOMINAL DYN. PRESS.(PSF) VS. TIME (SEC)					
0.	99.92	3.84	76.65	8.84	56.36	
13.84	42.73	18.84	33.18	23.84	25.49	
28.84	18.20	33.84	11.95	38.84	5.89	
43.84	2.28					
24	BOOSTER THRUST(LBS) VS. TIME (SEC)					
0.	40000.	0.43	40643.	6.75	51961.4	
12.53	61736.2	20.24	71254.0	25.54	73568.9	
30.84	70482.1	34.5	69967.6	35.86	63794.0	
36.77	10289.4	38.06	1029.0	39.32	0.	
12	BOOSTER PROPELLANT WEIGHT REMAINING (LBS) VS. TIME (SEC)					
0.	8274.34	9.63	6548.78	20.24	4077.25	
28.91	1844.78	35.65	188.52	39.32	0.	
18	NOMINAL PITCH ATTITUDE (DEG) VS. TIME(SEC)					
0.	30.58	3.84	29.72	8.84	28.21	
13.84	26.97	18.84	25.73	23.84	24.50	
28.84	23.60	33.84	22.86	43.84	21.24	
12	VELOCITY (FT/SEC) VS. TIME (SEC)					
0.	4394.	8.84	5183.	18.84	6666.	
28.84	8849.	38.84	10897.	43.84	10839.	
18	NOMINAL FLIGHT PATH ANGLE(DEG) VS. TIME(SEC)					
0.	31.05	3.84	29.75	8.84	28.18	
13.84	26.79	18.84	25.59	23.84	24.53	
28.84	23.62	33.84	22.86	43.84	21.58	
6	NOMINAL AZIMUTH(DEG) VS. TIME(SEC)					
0.	182.79	18.84	182.842	43.84	182.90	
6	NOMINAL ANGLE OF SIDESLIP(DEG) VS. TIME (SEC)					
0.	0.16	18.84	0.20	43.84	0.23	

FIGURE 7 (Concluded)  
Sample Problem Input IO(8)=0

8	MEAN WIND VELOCITY(FT/SEC) VS. ALTITUDE(FEET)				
120000.	120.	160000.	260.	220000.	310.
400000.	310.				
8	SIGMA WIND VELOCITY(FT/SEC) VS. ALTITUDE(FEET)				
120000.	75.	160000.	100.	220000.	100.
400000.	100.				
10	ALTITUDE (FEET) VS. TIME (SEC)				
0.	124795.	8.84	145378.	18.84	171644.
28.84	203371.	43.84	262430.		
*EOR					



Figure 8  
Sample Problem Input IO(8) = 1

1	799	2	3	2	1	12	4	1	1	0	000001
SAMPLE PROBLEM SCOUT SECOND STAGE, FUEL OPTION, FILTER OUT IN											000002
COAST, SEPARATE COAST CONTROL, NO YAW-ROLL MIXING IO(8)=1											000003
274625699253066457 INITIAL RANDOM SEQ NO RANF											000004
	0.	49241.45		282.07	IYY AND XCG @IGNITION (SLUG-					000005	
	0.5	41574.21		258.47	@50% PROP FT**2)					000006	
	1.0	27991.96		206.73	@BURNOUT					000007	
	19.	NO. OF SAMPLES FOR CORR COEFF								000008	
	-0.573	CORR COEFF PITCH								000009	
	-0.756	CORR COEFF YAW								000010	
	467.76	CONTROL MOTOR STATION								000011	
	14.93	CONTROL MOTOR LAT. LOC. (IN.)								000012	
	448.51	BOOSTER NOZZLE THROAT STATION								000013	
	16.89	ROLL CONTROL MOTOR ARM (IN.)								000014	
	1.	COS OF CANT ANGLE (NO CANT)								000015	
	0.	SIN OF CANT ANGLE (NO CANT)								000016	
	42.32	FILTER IN TIME (SEC)								000017	
	34.92	COAST TIME (SEC)								000018	
	167.	CONTROL FUEL (LB)								000019	
	35.86	T WEB (SEC)								000020	
	39.32	T BURNOUT (SEC)								000021	
	6968.26	WEIGHT B/O (LB)								000022	
	205.40	IXX B/O (SLUG-FT**2)								000023	
	30.32	CNAS FT2/RAD								000024	
	134.2	XCP STATION								000025	
	0.30	FLIGHT PATH ERROR (DEG)								000026	
	0.38	AZIMUTH ERROR (DEG)								000027	
	0.12	Q FRACTION SIGMA								000028	
	1.25		0.080	PITCH/YAW MOTOR OVERSHOOT RATIO						000029	
	0.019		0.0047	PITCH/YAW MOTOR TIME TO PEAK (SEC)						000030	
	0.012		0.001	T2 FLEX FILTER OUT COAST (SEC)						000031	
	0.0816		0.0271	INITIAL ET PITCH (DEG)						000032	
	0.0098		0.0239	INITIAL ET YAW (DEG)						000033	
	-0.000193		0.000753	SLOPE OF ET PITCH (DEG/SEC)						000034	

FIGURE 8 (Continued)  
Sample Problem Input IO(8)=1

-0.000302	0.000830	SLOPE OF ET YAW (DEG/SEC)	000035
125.	0.	BOOST CONTROL ISP (SEC)	000036
-0.098	0.326	INITIAL PITCH RATE (DEG/SEC)	000037
0.292	0.340	INITIAL PITCH ERROR (DEG)	000038
0.085	0.197	INITIAL YAW RATE (DEG/SEC)	000039
0.0105	0.243	INITIAL YAW ERROR (DEG)	000040
0.	0.	BOOSTER ROLL ANG. IMPULSE (FT-LB-SEC)	000041
0.	0.3817	PITCH/YAW JET MISALIGNMENT (DEG)	000042
259.0	20.0	WIND AZIMUTH (DEG)	000043
0.0166	0.0033	IYY AND XCG STANDARD DEVIATION	000044
0.	10.	PITCH STATIC UNBALANCE (FT-LB)	000045
0.	10.	YAW STATIC UNBALANCE (FT-LB)	000046
0.0459	0.0034	FILTER DELAY TIME (SEC)	000047
0.0093	0.0017	PITCH /YAW GYRO DELAY TIME (SEC)	000048
0.0715	0.0088	PITCH/YAW MOTOR T1 (SEC)	000049
0.0355	0.0052	PITCH/YAW MOTOR T2 (SEC)	000050
0.5	0.01667	KR/KD (SEC)	000051
0.802	0.0267	BOOST PITCH/YAW DEADBANDS (DEG)	000052
0.035	0.0167	BOOST PITCH/YAW HYSTERESIS (FRACTION)	000053
517.3	14.5	BOOST PITCH YAW CONTROL FORCE (LB)	000054
0.0069	0.0008	ROLL RATE GYRO DELAY (SEC)	000055
0.0251	0.0048	BOOST ROLL MOTOR T1 (SEC)	000056
0.0162	0.0030	BOOST ROLL MOTOR T2 (SEC)	000057
0.45	0.015	ROLL GAIN RATIO KR/KD (SEC)	000058
1.432	0.0478	BOOST ROLL DEADBAND (DEG)	000059
0.035	0.0167	ROLL HYSTERESIS (FRACTION)	000060
45.45	1.68	BOOST ROLL MOTOR FORCE (LB)	000061
0.45		PITCH PROGRAM RATE CHANGE (DEG/SEC)	000062
0.		YAW PROGRAM RATE CHANGE (DEG/SEC)	000063
1.25		RETRO TIME (SEC)	000064
165.		RETRO ISP (SEC)	000065
0.785	0.0267	PITCH YAW COAST DEADBANDS (DEG)	000066
517.3	14.5	COAST PITCH MOTOR THRUST (LB)	000067
0.0715	0.0088	COAST PITCH MOTOR T1 (SEC)	000068

FIGURE 8 (Concluded)  
Sample Problem Input IO(8)=1

	0.0355	0.0052	COAST PITCH MOTOR T2 (SEC)			000069
	1.432	0.0478	COAST ROLL DEADBAND (DEG)			000070
	45.45	1.68	COAST ROLL MOTOR THRUST (LB)			000071
	0.0251	0.0048	ROLL MOTOR T1 (SEC)			000072
	0.0162	0.0030	ROLL MOTOR T2 (SEC)			000073
	125.		COAST ISP (SEC)			000074
100.	4394.	31.05	4.2	INITIAL Q,U,GAMMA,CDS		000075
24		BOOSTER THRUST TIME HISTORY				000076
0.	40000.	0.43	40643.	6.75	51961.4	000077
12.53	61736.2	20.24	71254.0	25.54	73568.9	000078
30.84	70482.1	34.5	69967.6	35.86	63794.0	000079
36.77	10289.4	38.06	1029.0	39.32	0.	000080
12		BOOSTER PROPELLANT WEIGHT REMAINING TIME HISTORY				000081
0.	8274.34	9.63	6548.78	20.24	4077.25	000082
28.91	1844.78	35.65	188.52	39.32	0.	000083
18		THETA - GAMMA VS. TIME				000084
0.	-0.47	3.84	-0.03	8.84	0.03	000085
13.84	0.18	18.84	0.14	23.84	-0.03	000086
28.84	-0.02	33.84	0.00	43.84	-0.34	000087
6		AZIMUTH VS. TIME				000088
0.	182.79	18.84	182.842	43.84	182.90	000089
6		BETA NOMINAL VS. TIME				000090
0.	0.16	18.84	0.20	43.84	0.23	000091
8		MEAN WIND VS. ALTITUDE				000092
120000.	120.	160000.	260.	220000.	310.	000093
400000.	310.					000094
8		SIGMA WIND VS. ALTITUDE				000095
120000.	75.	160000.	100.	220000.	100.	000096
400000.	100.					000097
*EOR						

Figure 9  
Sample Output - Individual Cases - IO(1) = 1

RUN NO. 1  
SAMPLE PROBLEM SCOUT SECOND STAGE, FUEL OPTION, FILTER OUT IN  
COAST, SEPARATE COAST CONTROL, NO YAW-ROLL MIXING IO(1)=1

PAGE NO. 1

RUN NO. 1		PAGE NO. 2							
SMPL	CAPT IMP (LB-SEC) CST FUEL (POUNDS)	ROLL TORQ IMP(LB-SC) FLOW RATE FILTER IN	BOOST IMP (LB-SEC) DB RED TORQ FUEL(LBS)	T(UEB) (SEC) FLOW RATE COAST	T(TO) (SEC) RETRO TIME (SEC)	BOOST FUEL (LBS) NO. OF DB BOOST P-Y	ISP (SEC) OVERSHOOTS CST P-Y	TOTAL FUEL (LBS)	
1	5.4646E+02 1.8943E+01	0. 1.7264E+00	6.1790E+03 1.5804E+00	3.5860E+01 3.9416E-01	3.4600E+00 5.9620E+00	4.9432E+01 0	1.2500E+02 0	6.9956E+01	
2	5.4880E+02 2.1980E+01	0. 1.4532E+00	4.9719E+03 1.5806E+00	3.5860E+01 5.0459E-01	3.4600E+00 6.5670E+00	3.9775E+01 0	1.2500E+02 0	6.3336E+01	
3	5.5086E+02 1.5582E+01	0. 1.4637E+00	8.2154E+03 1.3367E+00	3.5860E+01 3.2048E-01	3.4600E+00 5.2454E+00	6.5723E+01 0	1.2500E+02 0	8.2642E+01	
4	5.3516E+02 1.9809E+01	0. 1.6219E+00	7.4289E+03 1.5676E+00	3.5860E+01 4.2794E-01	3.4600E+00 5.2437E+00	5.9431E+01 0	1.2500E+02 0	8.0809E+01	
5	4.6822E+02 1.4933E+01	0. 1.2776E+00	4.5942E+03 1.4241E+00	3.5860E+01 3.1786E-01	3.4600E+00 7.2418E+00	3.6753E+01 0	1.2500E+02 0	5.3110E+01	
6	4.7494E+02 2.1593E+01	0. 1.5006E+00	6.7367E+03 1.5498E+00	3.5860E+01 4.8943E-01	3.4600E+00 5.4432E+00	5.3894E+01 0	1.2500E+02 0	7.7037E+01	
7	4.4536E+02 2.2065E+01	0. 1.5464E+00	7.9478E+03 1.6535E+00	3.5860E+01 4.9901E-01	3.4600E+00 5.0415E+00	6.3582E+01 0	1.2500E+02 0	8.7301E+01	
8	5.8024E+02 1.7617E+01	0. 1.3197E+00	7.3045E+03 1.5743E+00	3.5860E+01 3.9111E-01	3.4600E+00 5.6574E+00	5.8436E+01 0	1.2500E+02 0	7.7627E+01	
9	4.1940E+02 1.3521E+01	0. 1.4828E+00	6.6580E+03 1.4131E+00	3.5860E+01 2.5981E-01	3.4600E+00 5.9898E+00	5.3264E+01 0	1.2500E+02 0	6.8198E+01	
10	4.7358E+02 1.7026E+01	0. 1.2577E+00	5.4370E+03 1.4490E+00	3.5860E+01 3.7951E-01	3.4600E+00 6.4751E+00	4.3496E+01 0	1.2500E+02 0	6.1971E+01	
11	5.4062E+02 2.0306E+01	0. 1.5617E+00	4.7588E+03 1.5992E+00	3.5860E+01 4.4735E-01	3.4600E+00 6.6078E+00	3.8071E+01 0	1.2500E+02 0	5.9976E+01	
12	3.4429E+02 2.1519E+01	0. 1.1722E+00	5.2625E+03 1.6102E+00	3.5860E+01 5.1553E-01	3.4600E+00 6.4652E+00	4.2100E+01 0	1.2500E+02 0	6.5229E+01	
13	6.0959E+02 1.9598E+01	0. 1.8900E+00	8.1023E+03 1.5984E+00	3.5860E+01 3.9885E-01	3.4600E+00 4.9586E+00	6.4819E+01 0	1.2500E+02 0	8.6015E+01	
14	5.2931E+02 2.2609E+01	0. 1.5378E+00	5.0268E+03 1.6542E+00	3.5860E+01 5.1534E-01	3.4600E+00 6.2493E+00	4.0214E+01 0	1.2500E+02 0	6.4478E+01	
15	4.5577E+02 2.1728E+01	0. 1.3950E+00	8.6983E+03 1.6270E+00	3.5860E+01 5.0236E-01	3.4600E+00 4.5541E+00	6.9586E+01 0	1.2500E+02 0	9.2941E+01	

Figure 10  
Sample Output - Discrete Probability

RUN NO. 1  
SAMPLE PROBLEM SCOUT SECOND STAGE, FUEL OPTION, FILTER OUT IN  
COAST, SEPARATE COAST CONTROL, NO YAW-ROLL MIXING IO(8)=0

PAGE NO. 1

RUN NO. 1

PAGE NO. 2

PROBABILITY	BOOST FUEL (POUNDS)	COAST FUEL (POUNDS)	RETRO TIME (SECONDS)	TOTAL FUEL (POUNDS)
.00200	22.729	11.891	7.8529	39.521
.00400	22.936	12.501	7.7257	43.684
.00600	24.861	12.974	7.7145	43.999
.00800	25.540	13.063	7.6578	44.486
.01000	26.821	13.068	7.6064	46.934
.01200	27.694	13.135	7.5769	47.270
.01400	28.001	13.521	7.4796	47.389
.01600	28.113	13.585	7.4234	48.100
.01800	29.158	13.699	7.3787	49.333
.02000	29.747	13.790	7.3498	49.605
.02200	29.908	13.816	7.3384	49.613
.02400	29.977	13.831	7.3149	49.775
.02600	30.128	13.908	7.3149	50.301
.02800	30.509	14.081	7.2684	50.362
.03000	30.728	14.214	7.2443	50.501
.03200	30.789	14.269	7.2418	50.506
.03400	31.044	14.380	7.2233	50.588
.03600	31.075	14.438	7.2182	50.635
.03800	31.220	14.688	7.1969	50.878
.04000	31.401	14.770	7.1951	50.890
.04200	31.560	14.787	7.1945	51.082
.04400	31.592	14.788	7.1917	52.219
.04600	32.336	14.814	7.1916	52.263
.04800	32.589	14.889	7.1857	52.338
.05000	32.621	14.894	7.1787	52.451
.05200	32.631	14.933	7.1600	52.632
.05400	32.892	14.943	7.1310	52.684
.05600	32.958	14.985	7.1260	52.758
.05800	32.985	15.018	7.1168	52.878
.06000	33.041	15.029	7.1086	52.889
.06200	33.046	15.042	7.1039	53.110
.06400	33.318	15.184	7.0836	53.213
.06600	33.516	15.255	7.0688	53.277
.06800	33.575	15.288	7.0657	53.459
.07000	33.615	15.332	7.0648	53.602
.07200	33.705	15.369	7.0565	53.786
.07400	33.994	15.397	7.0413	53.943
.07600	34.049	15.416	7.0124	54.014
.07800	34.125	15.429	7.0119	54.033
.08000	34.126	15.445	6.9678	54.088
.08200	34.196	15.469	6.9607	54.268
.08400	34.445	15.558	6.9453	54.348
.08600	34.635	15.582	6.9426	54.569
.08800	34.791	15.593	6.9342	54.574
.09000	34.815	15.602	6.9309	54.596
.09200	34.907	15.631	6.9213	54.607
.09400	34.927	15.668	6.9161	54.615
.09600	35.373	15.674	6.8917	54.845

FIGURE 10 (Continued)  
Sample Output - Discrete Probability

RUN NO. 1				PAGE NO. 4
PROBABILITY	BOOST FUEL (POUNDS)	COAST FUEL (POUNDS)	RETRO TIME (SECONDS)	TOTAL FUEL (POUNDS)
.21400	39.907	17.418	6.5874	61.250
.21600	39.964	17.432	6.5818	61.314
.21800	39.994	17.464	6.5740	61.382
.22000	40.063	17.468	6.5670	61.446
.22200	40.185	17.485	6.5666	61.449
.22400	40.214	17.494	6.5665	61.453
.22600	40.214	17.502	6.5606	61.479
.22800	40.258	17.514	6.5529	61.537
.23000	40.269	17.553	6.5400	61.663
.23200	40.351	17.554	6.5394	61.676
.23400	40.476	17.567	6.5382	61.826
.23600	40.570	17.573	6.5342	61.830
.23800	40.629	17.590	6.5330	61.887
.24000	40.637	17.602	6.5262	61.896
.24200	40.654	17.608	6.5208	61.904
.24400	40.832	17.615	6.5168	61.925
.24600	40.845	17.617	6.5150	61.954
.24800	40.853	17.618	6.5145	61.971
.25000	40.948	17.621	6.5135	62.216
.25200	41.079	17.650	6.5103	62.230
.25400	41.175	17.686	6.5087	62.313
.25600	41.440	17.700	6.5080	62.314
.25800	41.510	17.703	6.5076	62.489
.26000	41.697	17.706	6.5062	62.701
.26200	41.792	17.725	6.5051	62.744
.26400	41.803	17.727	6.5021	62.846
.26600	41.805	17.728	6.4869	62.929
.26800	41.832	17.729	6.4861	62.969
.27000	41.871	17.746	6.4786	62.976
.27200	41.934	17.748	6.4772	63.046
.27400	41.982	17.754	6.4751	63.067
.27600	42.088	17.754	6.4729	63.138
.27800	42.100	17.755	6.4674	63.151
.28000	42.114	17.785	6.4652	63.216
.28200	42.226	17.836	6.4492	63.238
.28400	42.232	17.855	6.4452	63.336
.28600	42.305	17.907	6.4433	63.386
.28800	42.312	17.912	6.4404	63.405
.29000	42.342	17.966	6.4383	63.598
.29200	42.400	17.980	6.4272	63.604
.29400	42.429	18.004	6.4260	63.613
.29600	42.476	18.028	6.4244	63.645
.29800	42.477	18.039	6.4130	63.787
.30000	42.528	18.047	6.4120	63.854
.30200	42.578	18.062	6.4017	63.855
.30400	42.601	18.073	6.3978	63.948
.30600	42.627	18.129	6.3946	64.085
.30800	42.775	18.138	6.3920	64.117
.31000	42.841	18.144	6.3819	64.136
.31200	42.873	18.154	6.3777	64.182
.31400	43.036	18.154	6.3767	64.188
.31600	43.050	18.167	6.3755	64.244
.31800	43.126	18.169	6.3753	64.258

FIGURE 10 (Continued)  
Sample Output - Discrete Probability

RUN NO.	1				PAGE NO.	5
PROBABILITY	BOOST FUEL (POUNDS)	COAST FUEL (POUNDS)	RETRO TIME (SECONDS)	TOTAL FUEL (POUNDS)		
.32000	43.171	18.184	6.3741	64.296		
.32200	43.388	18.187	6.3741	64.421		
.32400	43.421	18.194	6.3654	64.478		
.32600	43.496	18.225	6.3602	64.633		
.32800	43.895	18.231	6.3567	64.706		
.33000	43.917	18.264	6.3550	64.779		
.33200	43.984	18.308	6.3451	64.779		
.33400	44.205	18.327	6.3367	64.867		
.33600	44.211	18.329	6.3316	64.868		
.33800	44.231	18.335	6.3310	64.879		
.34000	44.294	18.355	6.3298	64.908		
.34200	44.320	18.364	6.3261	64.944		
.34400	44.343	18.383	6.3198	64.973		
.34600	44.371	18.384	6.3173	65.018		
.34800	44.429	18.388	6.3138	65.095		
.35000	44.473	18.390	6.3113	65.116		
.35200	44.628	18.405	6.3029	65.118		
.35400	44.679	18.407	6.3011	65.229		
.35600	44.715	18.408	6.2877	65.259		
.35800	44.869	18.408	6.2817	65.283		
.36000	44.938	18.423	6.2786	65.527		
.36200	44.962	18.427	6.2757	65.582		
.36400	44.969	18.453	6.2754	65.588		
.36600	45.046	18.466	6.2754	65.656		
.36800	45.219	18.489	6.2746	65.744		
.37000	45.255	18.492	6.2732	65.778		
.37200	45.286	18.504	6.2582	65.781		
.37400	45.307	18.511	6.2549	65.805		
.37600	45.447	18.535	6.2493	65.833		
.37800	45.485	18.549	6.2482	65.841		
.38000	45.568	18.578	6.2460	65.939		
.38200	45.645	18.585	6.2459	65.967		
.38400	45.776	18.608	6.2446	66.279		
.38600	45.811	18.615	6.2398	66.590		
.38800	45.870	18.636	6.2376	66.627		
.39000	45.927	18.665	6.2278	66.727		
.39200	45.928	18.681	6.2221	66.772		
.39400	46.014	18.688	6.2110	66.832		
.39600	46.110	18.690	6.2088	66.875		
.39800	46.214	18.698	6.2056	66.887		
.40000	46.215	18.723	6.2047	66.924		
.40200	46.283	18.729	6.2030	67.114		
.40400	46.527	18.753	6.2018	67.149		
.40600	46.559	18.766	6.1997	67.365		
.40800	46.561	18.772	6.1935	67.549		
.41000	46.657	18.775	6.1848	67.553		
.41200	46.669	18.785	6.1736	67.576		
.41400	46.733	18.790	6.1670	67.616		
.41600	46.806	18.796	6.1568	67.851		
.41800	46.832	18.803	6.1558	67.856		
.42000	47.022	18.827	6.1527	67.914		
.42200	47.040	18.848	6.1519	67.916		
.42400	47.049	18.856	6.1459	68.108		

FIGURE 10 (Continued)  
Sample Output - Discrete Probability

RUN NO.	1				PAGE NO.	6
PROBABILITY	BOOST FUEL (POUNDS)	COAST FUEL (POUNDS)	RETRO TIME (SECONDS)	TOTAL FUEL (POUNDS)		
.42600	47.095	18.896	6.1443	68.198		
.42800	47.185	18.900	6.1407	68.308		
.43000	47.266	18.943	6.1390	68.313		
.43200	47.272	18.945	6.1380	68.357		
.43400	47.331	18.946	6.1323	68.449		
.43600	47.522	18.950	6.1306	68.491		
.43800	47.525	18.984	6.1287	68.580		
.44000	47.534	18.986	6.1262	68.636		
.44200	47.545	18.987	6.1247	68.640		
.44400	47.654	19.018	6.1187	68.849		
.44600	47.774	19.019	6.1134	68.993		
.44800	47.831	19.049	6.1110	69.006		
.45000	47.910	19.052	6.1051	69.195		
.45200	47.958	19.075	6.1017	69.242		
.45400	48.006	19.084	6.0946	69.356		
.45600	48.034	19.091	6.0903	69.384		
.45800	48.235	19.099	6.0830	69.442		
.46000	48.266	19.102	6.0754	69.506		
.46200	48.321	19.209	6.0613	69.531		
.46400	48.329	19.234	6.0591	69.569		
.46600	48.337	19.248	6.0507	69.721		
.46800	48.435	19.274	6.0472	69.746		
.47000	48.446	19.287	6.0455	69.803		
.47200	48.541	19.292	6.0444	69.807		
.47400	48.590	19.296	6.0438	69.819		
.47600	48.710	19.306	6.0405	69.956		
.47800	48.765	19.316	6.0293	69.969		
.48000	48.769	19.321	6.0285	69.978		
.48200	48.830	19.328	6.0268	70.002		
.48400	48.835	19.355	6.0256	70.018		
.48600	48.835	19.355	6.0243	70.083		
.48800	48.870	19.433	6.0231	70.144		
.49000	48.872	19.454	6.0207	70.260		
.49200	48.984	19.458	6.0134	70.263		
.49400	49.116	19.463	6.0107	70.303		
.49600	49.168	19.476	6.0077	70.309		
.49800	49.172	19.482	6.0055	70.331		
.50000	49.188	19.500	5.9998	70.342		
.50200	49.201	19.521	5.9969	70.379		
.50400	49.432	19.555	5.9936	70.422		
.50600	49.435	19.558	5.9898	70.453		
.50800	49.492	19.564	5.9888	70.547		
.51000	49.506	19.583	5.9788	70.599		
.51200	49.534	19.589	5.9738	70.643		
.51400	49.585	19.598	5.9620	70.650		
.51600	49.601	19.600	5.9617	70.836		
.51800	49.676	19.602	5.9602	70.856		
.52000	49.753	19.607	5.9569	70.920		
.52200	49.796	19.621	5.9568	70.935		
.52400	49.963	19.631	5.9556	71.042		
.52600	50.000	19.659	5.9538	71.127		
.52800	50.010	19.668	5.9483	71.148		
.53000	50.094	19.688	5.9440	71.161		



FIGURE 10 (Continued)  
Sample Output - Discrete Probability

RUN NO. 1	PAGE NO. 7			
PROBABILITY	BOOST FUEL (POUNDS)	COAST FUEL (POUNDS)	RETRO TIME (SECONDS)	TOTAL FUEL (POUNDS)
.53200	50.112	19.779	5.9389	71.219
.53400	50.178	19.787	5.9324	71.220
.53600	50.178	19.789	5.9304	71.257
.53800	50.216	19.809	5.9277	71.355
.54000	50.221	19.819	5.9274	71.357
.54200	50.234	19.827	5.9217	71.387
.54400	50.349	19.832	5.9212	71.451
.54600	50.424	19.835	5.9181	71.463
.54800	50.494	19.839	5.9160	71.559
.55000	50.494	19.870	5.9067	71.641
.55200	50.601	19.880	5.9060	71.672
.55400	50.791	19.916	5.8960	71.770
.55600	50.965	19.948	5.8929	71.945
.55800	51.005	19.956	5.8915	71.982
.56000	51.117	19.974	5.8840	71.994
.56200	51.182	19.987	5.8829	72.079
.56400	51.263	20.004	5.8825	72.273
.56600	51.297	20.020	5.8770	72.298
.56800	51.316	20.032	5.8722	72.299
.57000	51.392	20.057	5.8647	72.312
.57200	51.569	20.093	5.8637	72.428
.57400	51.574	20.122	5.8626	72.453
.57600	51.593	20.129	5.8583	72.618
.57800	51.622	20.130	5.8541	72.549
.58000	51.671	20.167	5.8528	72.613
.58200	51.749	20.173	5.8508	72.757
.58400	51.858	20.182	5.8500	72.759
.58600	52.034	20.202	5.8487	72.783
.58800	52.036	20.210	5.8484	72.793
.59000	52.052	20.227	5.8451	72.796
.59200	52.146	20.269	5.8444	72.797
.59400	52.219	20.295	5.8345	72.890
.59600	52.260	20.296	5.8296	72.956
.59800	52.270	20.296	5.8291	73.001
.60000	52.299	20.306	5.8202	73.027
.60200	52.358	20.323	5.8199	73.221
.60400	52.364	20.341	5.8024	73.359
.60600	52.449	20.367	5.7955	73.362
.60800	52.580	20.376	5.7951	73.367
.61000	52.606	20.421	5.7934	73.437
.61200	52.609	20.435	5.7917	73.603
.61400	52.652	20.442	5.7913	73.658
.61600	52.705	20.470	5.7909	73.693
.61800	52.711	20.470	5.7898	73.713
.62000	52.748	20.514	5.7882	73.723
.62200	52.754	20.518	5.7789	73.797
.62400	52.760	20.567	5.7740	73.808
.62600	52.764	20.576	5.7736	73.911
.62800	53.038	20.577	5.7727	73.916
.63000	53.048	20.584	5.7558	73.916
.63200	53.077	20.591	5.7548	73.966
.63400	53.090	20.606	5.7527	73.980
.63600	53.090	20.617	5.7440	74.136

FIGURE 10 (Continued)  
Sample Output - Discrete Probability

RUN NO. 1	PAGE NO. 8			
PROBABILITY	BOOST FUEL (POUNDS)	COAST FUEL (POUNDS)	RETRO TIME (SECONDS)	TOTAL FUEL (POUNDS)
.63800	53.097	20.626	5.7361	74.184
.64000	53.189	20.653	5.7294	74.309
.64200	53.193	20.656	5.7271	74.446
.64400	53.241	20.692	5.7243	74.514
.64600	53.264	20.738	5.7239	74.521
.64800	53.284	20.740	5.7237	74.540
.65000	53.363	20.745	5.7235	74.576
.65200	53.367	20.777	5.7175	74.593
.65400	53.433	20.783	5.7170	74.855
.65600	53.479	20.786	5.7167	74.978
.65800	53.490	20.790	5.7130	74.985
.66000	53.654	20.798	5.7055	74.986
.66200	53.703	20.826	5.7024	75.333
.66400	53.712	20.831	5.6995	75.345
.66600	53.737	20.831	5.6959	75.503
.66800	53.847	20.835	5.6846	75.667
.67000	53.894	20.856	5.6665	75.667
.67200	53.952	20.893	5.6574	75.683
.67400	53.957	20.902	5.6522	75.782
.67600	54.207	20.923	5.6488	75.786
.67800	54.249	20.925	5.6453	75.798
.68000	54.258	20.926	5.6299	75.944
.68200	54.260	20.950	5.6232	76.181
.68400	54.395	20.952	5.6203	76.199
.68600	54.670	20.958	5.6190	76.259
.68800	54.688	20.962	5.6088	76.262
.69000	54.712	20.996	5.6075	76.296
.69200	54.724	20.996	5.6068	76.507
.69400	54.778	21.004	5.6034	76.513
.69600	55.158	21.018	5.6012	76.528
.69800	55.360	21.050	5.6011	76.569
.70000	55.501	21.063	5.6000	76.659
.70200	55.543	21.066	5.5975	76.856
.70400	55.575	21.099	5.5908	77.037
.70600	55.589	21.101	5.5865	77.050
.70800	55.729	21.103	5.5662	77.139
.71000	55.782	21.113	5.5640	77.147
.71200	55.791	21.191	5.5612	77.187
.71400	55.830	21.207	5.5575	77.277
.71600	56.070	21.216	5.5550	77.397
.71800	56.189	21.229	5.5491	77.420
.72000	56.274	21.231	5.5472	77.576
.72200	56.355	21.254	5.5467	77.627
.72400	56.449	21.307	5.5390	77.706
.72600	56.484	21.326	5.5162	77.797
.72800	56.585	21.334	5.5137	77.789
.73000	56.655	21.365	5.5117	77.902
.73200	56.907	21.366	5.4968	77.947
.73400	56.934	21.371	5.4824	78.102
.73600	57.041	21.371	5.4806	78.447
.73800	57.149	21.448	5.4665	78.452
.74000	57.191	21.460	5.4653	78.570
.74200	57.302	21.467	5.4591	78.581

FIGURE 10 (Continued)  
Sample Output - Discrete Probability

RUN NO. 1				PAGE NO. 10
PROBABILITY	BOOST FUEL (POUNDS)	COAST FUEL (POUNDS)	RETRO TIME (SECONDS)	TOTAL FUEL (POUNDS)
.85000	62.665	22.609	5.1219	84.236
.85200	63.013	22.650	5.1071	84.413
.85400	63.188	22.654	5.0959	84.601
.85600	63.270	22.663	5.0945	84.678
.85800	63.337	22.692	5.0834	84.767
.86000	63.506	22.801	5.0735	84.924
.86200	63.582	22.802	5.0699	85.190
.86400	63.624	22.951	5.0655	85.190
.86600	63.799	22.982	5.0541	85.192
.86800	63.813	23.014	5.0486	85.271
.87000	63.826	23.070	5.0468	85.417
.87200	63.930	23.077	5.0453	85.481
.87400	63.937	23.093	5.0415	85.504
.87600	64.092	23.176	5.0198	85.568
.87800	64.117	23.201	5.0158	85.699
.88000	64.150	23.322	5.0147	85.751
.88200	64.245	23.331	5.0141	85.790
.88400	64.344	23.413	5.0107	86.015
.88600	64.380	23.428	5.0060	86.266
.88800	64.668	23.474	5.0052	86.336
.89000	64.722	23.482	4.9907	86.846
.89200	64.724	23.521	4.9804	86.867
.89400	64.819	23.577	4.9651	87.128
.89600	64.869	23.641	4.9637	87.180
.89800	64.872	23.791	4.9586	87.249
.90000	64.875	23.801	4.9474	87.301
.90200	65.005	23.815	4.9413	87.312
.90400	65.069	23.831	4.9369	87.683
.90600	65.277	23.862	4.9348	87.966
.90800	65.661	23.874	4.9287	87.997
.91000	65.723	23.877	4.9129	88.032
.91200	65.825	23.894	4.9122	88.115
.91400	65.828	23.916	4.8993	88.206
.91600	66.388	23.936	4.8838	88.279
.91800	66.459	24.061	4.8807	88.403
.92000	66.622	24.101	4.8519	88.424
.92200	66.632	24.128	4.8263	88.505
.92400	67.039	24.165	4.8256	88.575
.92600	67.070	24.168	4.8201	88.689
.92800	67.523	24.258	4.8171	88.695
.93000	67.777	24.644	4.7769	88.942
.93200	67.874	24.648	4.7689	89.188
.93400	68.122	24.660	4.7554	89.804
.93600	68.917	24.708	4.7533	90.211
.93800	69.023	24.759	4.7531	90.608
.94000	69.147	24.775	4.7311	90.716
.94200	69.174	24.808	4.7290	90.846
.94400	69.290	24.829	4.7185	90.960
.94600	69.449	24.890	4.7021	91.055
.94800	69.573	24.891	4.6766	91.302
.95000	69.586	24.943	4.6613	91.540
.95200	70.021	24.943	4.6002	91.644
.95400	70.136	24.959	4.5862	91.754

FIGURE 10 (Concluded)  
Sample Output - Discrete Probability

RUN NO. 1					PAGE NO. 11
PROBABILITY	BOOST FUEL (POUNDS)	COAST FUEL (POUNDS)	RETRO TIME (SECONDS)	TOTAL FUEL (POUNDS)	
.95600	70.160	25.029	4.5736	92.110	
.95800	70.372	25.107	4.5541	92.238	
.96000	70.547	25.268	4.5511	92.941	
.96200	71.412	25.312	4.5382	93.462	
.96400	71.468	25.530	4.4708	93.953	
.96600	71.545	25.570	4.4349	94.400	
.96800	71.700	25.681	4.3756	95.466	
.97000	72.882	25.694	4.3737	95.693	
.97200	73.257	25.695	4.3540	96.082	
.97400	73.411	25.698	4.3376	96.688	
.97600	73.417	25.798	4.3165	96.732	
.97800	73.968	26.164	4.2579	97.255	
.98000	74.278	26.615	4.2546	97.645	
.98200	74.386	26.666	4.2486	99.132	
.98400	76.124	26.726	4.1131	99.869	
.98600	77.220	26.766	4.1107	100.913	
.98800	77.593	26.874	3.9945	101.108	
.99000	77.897	28.161	3.9288	102.675	
.99200	78.030	28.779	3.9255	102.800	
.99400	78.164	28.882	3.7219	106.610	
.99600	85.715	30.642	3.5038	109.539	
.99800	88.123	30.970	3.3252	113.315	

Figure 11  
Output Page of Sample Statistical Data

RUN NO.        1

PAGE NO.

SAMPLE PROBLEM SCOUT SECOND STAGE, FUEL OPTION, FILTER OUT IN  
COAST, SEPARATE COAST CONTROL, NO YAW-ROLL MIXING IO(8)=0

	BOOST FUEL	COAST FUEL	RETRO TIME	TOTAL FUEL
MEAN	49.783	19.660	5.9572	70.988
STD. DEVIATION	11.490	3.029	.7685	12.132
0.995 PROB	88.179	31.395	3.3356	112.182
0.95 CONFID				

FINAL VALUE OF RANDOM SEQUENCE INTEGER    =    274469945168434565

NO. OF SAMPLES WITH DEADBAND OVERSHOOT

BOOST(PITCH AND YAW)	=	0
(ROLL)	=	0
COAST	=	0

Figure 12  
Summary Statistics and Level of Significance

DISTRIBUTION FUNCTION FIT			
	BOOST	COAST	TOTAL
NORMAL DISTRIBUTION			
MEAN	49.783	19.660	70.988
STANDARD DEV	11.478	3.026	12.120
SKEWNESS	.302	.363	.342
KURTOSIS	2.744	3.408	2.987
0.995 PROB 0.95 CONF	81.378	27.990	104.350
LEVEL OF SIGNIFICANCE	.035	.044	.014
LOG NORMAL DISTRIBUTION (VALUES OF LOG)			
MEAN	3.880	2.967	4.248
STANDARD DEV	.236	.154	.172
SKEWNESS	-.275	-.134	-.125
KURTOSIS	2.792	3.142	2.858
0.995 PROB 0.95 CONF	92.777	29.722	112.184
LEVEL OF SIGNIFICANCE	.107	.756	.516
WEIBULL DISTRIBUTION			
PARAMETERS A	21.6359	12.5937	42.2023
B	31.6198	7.9491	32.3661
C	2.6618	2.5267	2.5726
PROBABILITY 0.5000	49.201	19.473	70.284
0.9900	77.734	27.136	100.777
0.9950	80.801	27.974	104.092
0.9990	86.965	29.667	110.776
LEVEL OF SIGNIFICANCE	.637	.003	.293

Figure 13  
Histogram Output

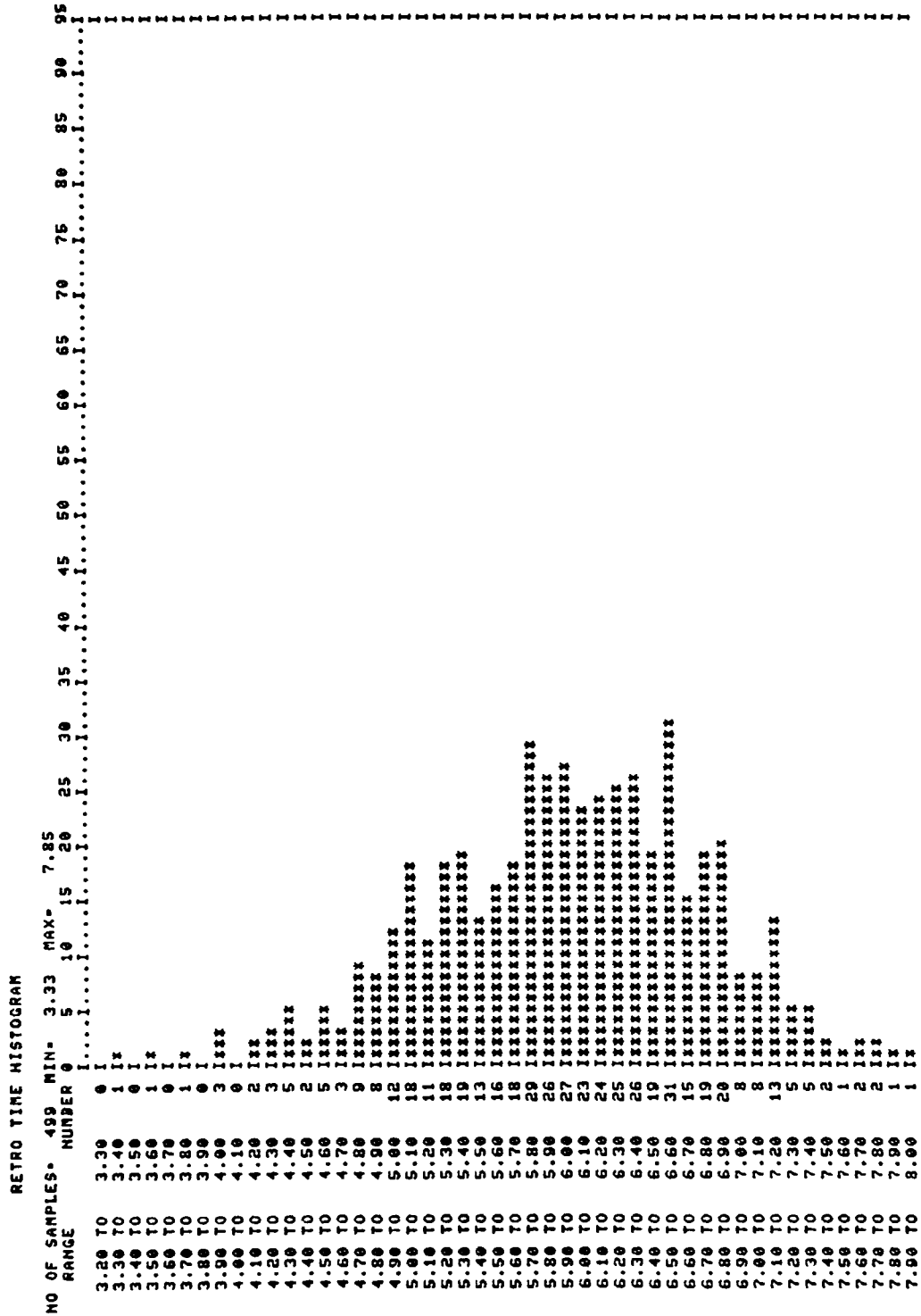


Figure 13 (Cont.)  
Histogram Output

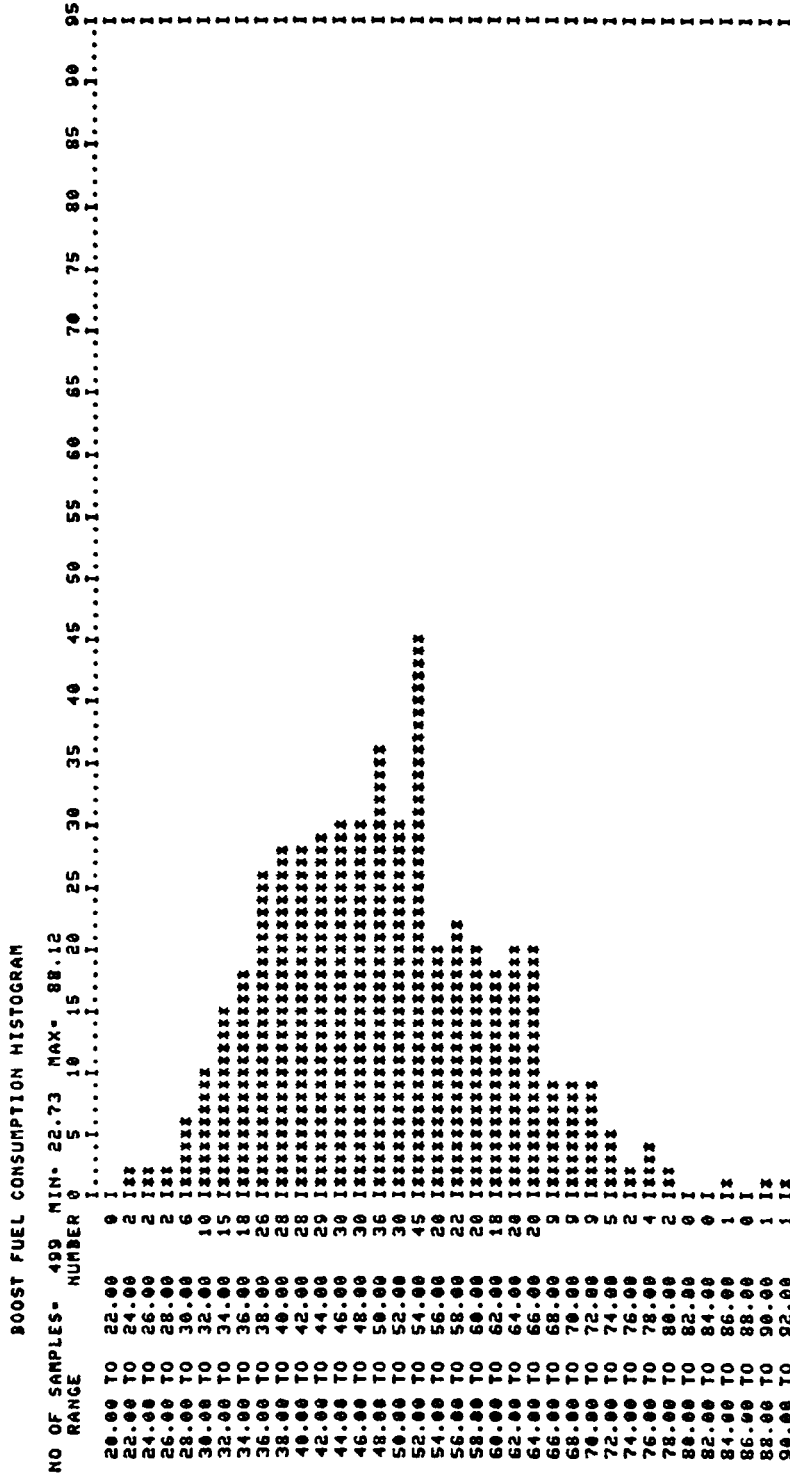




Figure 13 (Cont.)  
Histogram Output

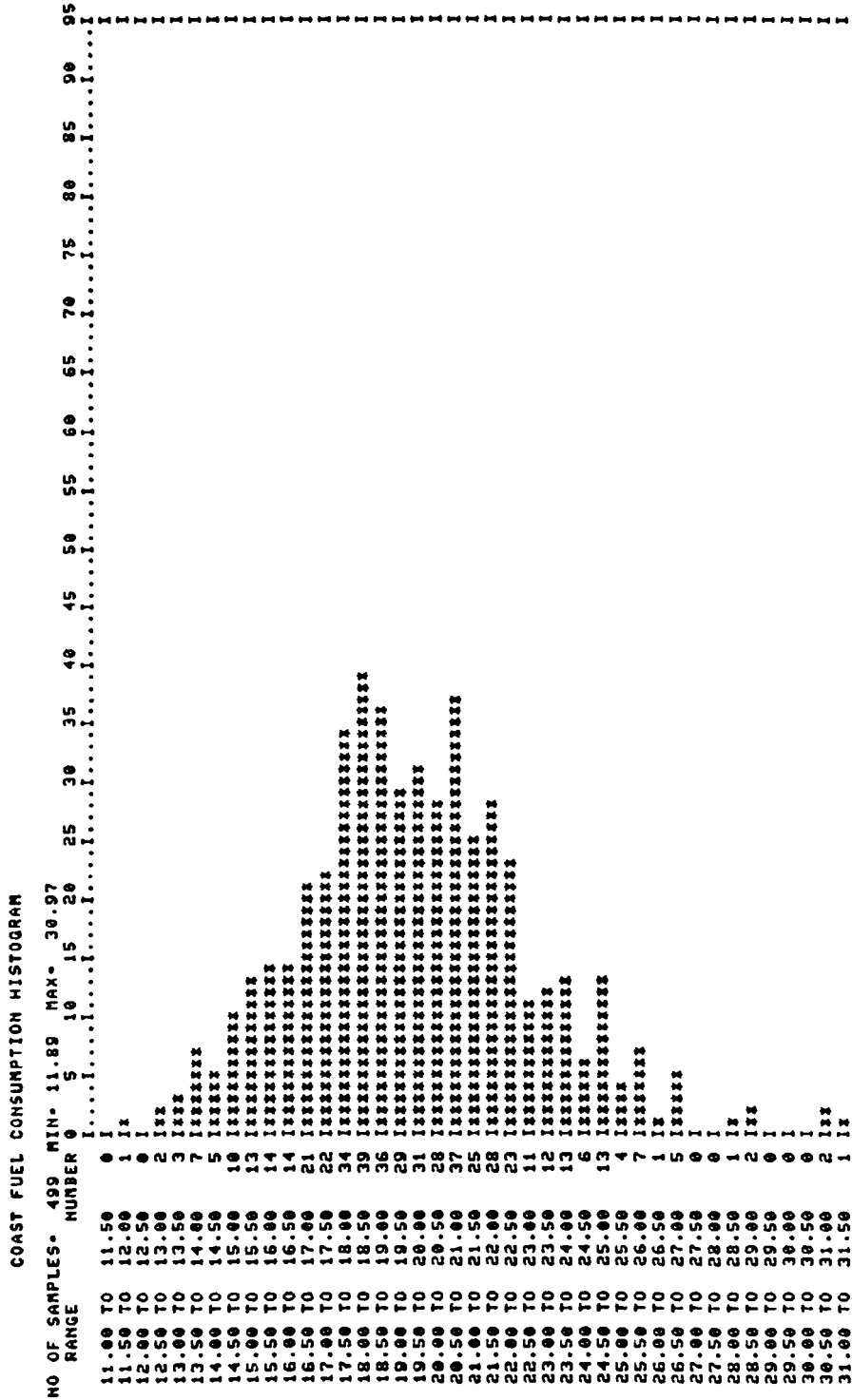
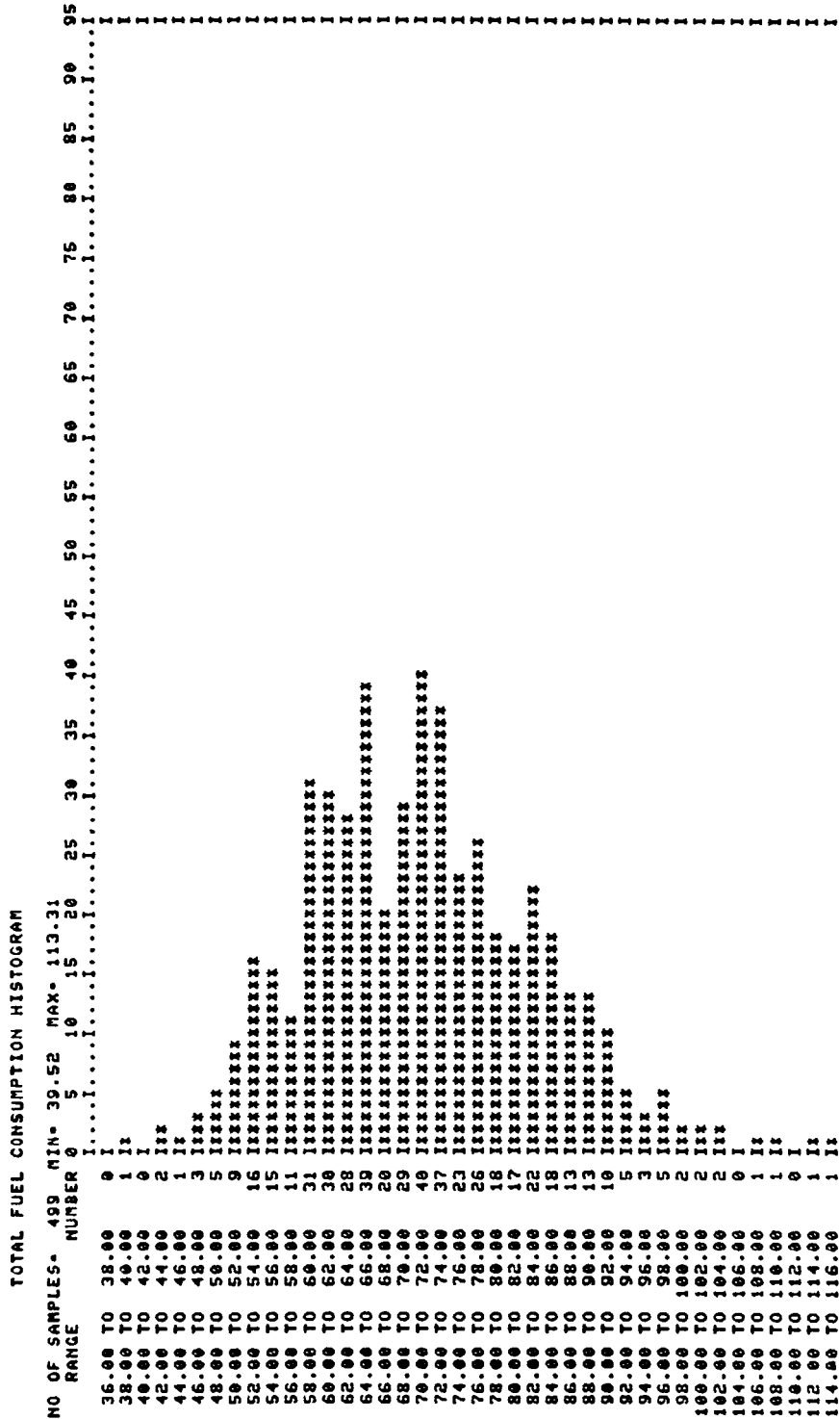


Figure 13 (Concluded)  
Histogram Output



## APPENDIX A

### FORTTRAN Program Listing

A complete listing of the FORTRAN Source Program is presented in the following pages. It starts with the MAIN routine and is followed by the seventeen (17) subroutines arranged in alphabetical order. There are a total of 947 cards in the MAIN routine. The total program including the subroutines contains 1,626 cards.

If the routine is used on a non-CDC computer the pseudo random number generation will change. In this case the calls to RANSET (line 29) and RANGET (lines 668, 743, and 829) should be deleted. Subroutine RNDX has an alternate pseudo random number generator coding which is listed as comment cards.

```

*DECK MAIN
PROGRAM MAIN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C SCOUT UPPER STAGE STATISTICAL FUEL CONSUMPTION ROUTINE
C COMPUTES THE STATISTICAL DISTRIBUTION OF CONTROL FUEL CONSUMPTION
C FOR AN ON-OFF REACTION JET ATTITUDE CONTROL SYSTEM BY THE MONTE
C CARLO TECHNIQUE. THE EFFECT OF BOOSTER INDUCED DISTURBANCES AND
C AERODYNAMIC DISTURBANCES ARE CONSIDERED IN ADDITION TO THE SELF
C EXCITED LIMIT CYCLE MOTION.
  DIMENSION IO(9), A(16), TABL1(9), B(30), C(30), D(18), BT(15),
1  PC(8), YC(8), RC(7), PDC(10), WBOOST(1000), TCOAST(1000),
2  WCOAS(1000), TRET(1000), WTOT(1000), FWB(20), FWC(20), FWT(20),
3  TBL1(90), TBL2(90), TBL3(90), TBL4(90), TBL5(90), TBL6(90),
4  TBL7(90), TBL8(90), TBL9(90), TBL10(90), TBL11(90),
5  TA1(50), TCX(50), VXX(50), GAP(50), ZPX(50), PSX(50), HX(50),
6  VELX(50), X1KA(50), X1KB(50), VWMX(50), VWSX(50), THX(50), TOW(50),
7  WGHT(50), XINER(50), CNASQ(50)
  COMMON K, RXD(30)
  COMMON/DOUT/NQT, TBL1, NUT, TBL5, NGT, TBL6, NHT, TBL11, TBO, NTC, TBL4
  COMMON/DDI/TBL2, TBL3, NTHT, NWT, CDS, M2, M3, WBO
  DATA NUMCHI/11/
C READ RUN NO., NUMBER OF SAMPLES, AND RUN OPTIONS
10 READ( 5,1330) NRUN,IT,(IO(I),I=1,9)
  IF (EOF(5).NE.0) STOP
C READ TWO CARDS OF TITLE INFORMATION FOR OUTPUT ONLY
  READ( 5,1350)
C READ INITIAL SEQUENCE INTEGER FOR RANF PSEUDO RANDOM NUMBER
  READ( 5,1320) K
  CALL RANSET (K)
  NPAGE=1
  NLINE=0
  CALL PAGEHD (NRUN,NPAGE,NLINE)
  WRITE( 6,1350)
  NLINE=NLINE+2

```

C	READ IN XCG AND MOMENT OF INERTIA TABLE	35
	READ( 5,1440) (TABL1(I),I=1,9)	36
C	READ IN SINGLE VALUED CONSTANTS	37
	READ( 5,1450) (A(I),I=1,16),CNAS,XCP,GAMEI,ZEI,QFRAC	38
	TBO=A(14)	39
	WBO=A(15)	40
	GAMEI=GAMEI/57.3	41
	ZEI=ZEI/57.3	42
C	READ IN MEAN AND STANDARD DEVIATIONS OF CONTROL MOTOR OVERSHOOT	43
C	RATIO,TIME TO PEAK THRUST, ADDED TURN-OFF TIME DELAY DUE TO	44
C	STRUCTURAL FLEXIBILITY	45
	READ( 5,1460) ORM,ORS,TPM,TPS,T2FM,T2FS	46
C	READ IN MEAN AND STANDARD DEVIATIONS OF BOOST AND CONTROL SYSTEM	47
	READ( 5,1460) (B(I),I=1,30)	48
	READ( 5,1460) (C(I),I=1,30)	49
	IF (IO(2)-3 .LT. 0 ) GO TO 20	50
C	SEPARATE COAST CONTROL SYSTEM OPTION IO(2)=3	51
C	READ IN TORQUEING RATE CHANGES AND RETRO PARAMETERS	52
	READ( 5,1450) PTRC,YTRC,TRETRO,RETRSI	53
C	READ IN COAST CONTROL SYSTEM VARIABLES, MEAN AND SIGMA	54
	READ( 5,1460) (D(I),I=1,18)	55
C	READ IN TABLES	56
20	M2=1	57
	M3=1	58
C	TEST FOR INPUT OPTION TO CALCULATE OR READ IN Q,VEL,GAMMA,ALTITUDE	59
	IF (IO(8).EQ.0) GO TO 30	60
C	READ IN INITIAL Q,U,GAMMA AND DRAG COEFFICIENT CDS FOR CALCULATION	61
	READ( 5,990) QO,UO,GAMO,CDS	62
	READ( 5,1470) NTHT,(TBL2(I),I=1,NTHT)	63
	READ( 5,1470) NWT,(TBL3(I),I=1,NWT)	64
	READ( 5,1470) NTC,(TBL4(I),I=1,NTC)	65
	READ( 5,1470) NAZT,(TBL7(I),I=1,NAZT)	66
	READ( 5,1470) NSYT,(TBL8(I),I=1,NSYT)	67
	READ( 5,1470) NUMH,(TBL9(I),I=1,NUMH)	68

	READ( 5,1470) NVSH,(TBL10(I),I=1,NVSH)	69
C	CALCULATE Q,VELOCITY,GAMMA,AND ALTITUDE TABLES	70
	CALL TABGEN (QO,UO,GAMO)	71
	GO TO 40	72
C	IO(8)=0 READ IN ALL TRAJECTORY TABLES	73
30	READ( 5,1470) NQT,(TBL1(I),I=1,NQT)	74
	READ( 5,1470) NHT,(TBL2(I),I=1,NHT)	75
	READ( 5,1470) NWT,(TBL3(I),I=1,NWT)	76
	READ( 5,1470) NTC,(TBL4(I),I=1,NTC)	77
	READ( 5,1470) NUT,(TBL5(I),I=1,NUT)	78
	READ( 5,1470) NGT,(TBL6(I),I=1,NGT)	79
	READ( 5,1470) NAZT,(TBL7(I),I=1,NAZT)	80
	READ( 5,1470) NSYT,(TBL8(I),I=1,NSYT)	81
	READ( 5,1470) NUMH,(TBL9(I),I=1,NUMH)	82
	READ( 5,1470) NVSH,(TBL10(I),I=1,NVSH)	83
	READ( 5,1470) NHT,(TBL11(I),I=1,NHT)	84
C	COMPUTE CONSTANTS FOR SECOND ORDER CURVE FITTING MASS PROPERTIES	85
40	QR1=TABL1(7)/TABL1(4)	86
	QR2=TABL1(7)*(TABL1(7)-TABL1(4))	87
	SL2IY=(TABL1(8)-TABL1(2)+QR1*(TABL1(2)-TABL1(5)))/QR2	88
	SL1IY=(-TABL1(2)+TABL1(5)-SL2IY*TABL1(4)*TABL1(4))/TABL1(4)	89
	SL2CG=(TABL1(9)-TABL1(3)+QR1*(TABL1(3)-TABL1(6)))/QR2	90
	SL1CG=(-TABL1(3)+TABL1(6)-SL2CG*TABL1(4)*TABL1(4))/TABL1(4)	91
	NTB=IO(5)	92
	NTT=IO(6)	93
	MER1=0	94
	MRER1=0	95
	MERC=0	96
	NPK1=0	97
	NPK2=0	98
	NPK3=0	99
	NPK4=0	100
	SUB=0.	101
	STC=0.	102

	SWC=0.	103
	STR=0.	104
	SWT=0.	105
	ANTPW=IO(5)	106
	ANTPT=IO(6)	107
	TWEB=A(13)	108
	WTC=TBL3(2)	109
	DELT1=TWEB/ANTPW	110
	DELT2=(TBO-TWEB)/ANTPT	111
	PBFCT=0.0	112
	PCFCT=0.0	113
	YCFCT=0.0	114
	YBFCT=0.0	115
C	SET TABLE LOOKUP INDICES FOR INITIAL VALUE	116
	M1=1	117
	M2=1	118
	M3=1	119
	M4=1	120
	M5=1	121
	M6=1	122
	M7=1	123
	M8=1	124
	M9=1	125
	M10=1	126
	M11=1	127
	NTOT=NTB+NTT	128
	DELTA=DELT1	129
C		130
C	CALCULATE AND STORE THRUST MISALIGNMENT AND AERO COEFFICIENTS	131
C	AT TIME POINTS DURING BOOST PHASE	132
	TA=0.	133
	DO 50 J=1,NTOT	134
	IF(J.GT.NTB) DELTA=DELT2	135
	TA=TA+0.5*DELTA	136

TA1(J)=TA	137
CALL TBLU (NQT,Q,TA,TBL1,M1)	138
CALL TBLU (NHT,T,TA,TBL2,M2)	139
CALL TBLU (NWT,WR,TA,TBL3,M3)	140
CALL TBLU (NTC,TC,TA,TBL4,M4)	141
CALL TBLU (NVT,U,TA,TBL5,M5)	142
CALL TBLU (NGT,GAMP,TA,TBL6,M6)	143
CALL TBLU (NAZT,ZP,TA,TBL7,M7)	144
CALL TBLU (NSYT,BETPR,TA,TBL8,M8)	145
CALL TBLU (NHT,H,TA,TBL11,M11)	146
CALL TBLU (NUMH,UWM,H,TBL9,M9)	147
CALL TBLU (NUSH,UWS,H,TBL10,M10)	148
TCX(J)=TC/57.3	149
UXX(J)=U	150
GAP(J)=GAMP/57.3	151
ZPX(J)=ZP/57.3	152
PSX(J)=BETPR/57.3	153
UWMX(J)=UWM	154
UWSX(J)=UWS	155
HX(J)=H	156
PERCA=(WTC-WR)/WTC	157
WT2=WBO+WR	158
ACC=T*32.173/WT2	159
VELX(J)=ACC*DELTA*C(11)/57.3	160
CALCULATE MOMENT OF INERTIA AND XCG AVERAGE DURING WEB BURN	161
ERTIA=(TABL1(2)+SL1IY*PERCA+SL2IY*PERCA*PERCA)	162
CGA=(TABL1(3)+SL1CG*PERCA+SL2CG*PERCA*PERCA)	163
XERT=12.*ERTIA	164
THX(J)=((A(4)-CGA)*A(8)+A(5)*A(9))/XERT	165
X1KA(J)=CNAS*Q*(CGA-XCP)/XERT	166
X1KB(J)=(A(6)-CGA)*T/XERT	167
XINER(J)=ERTIA	168
TOW(J)=T/WT2	169
WGHT(J)=WT2	170



	CNASQ(J)=CNAS*Q	171
	50 CONTINUE	172
C		173
C	BEGIN THE MONTE CARLO RUNS	174
C		175
	DO 750 ITER=1,IT	176
C	CALCULATE AND TEST CONTROL MOTOR THRUST OVERSHOOT FACTORS	177
	IF (ORM-1.0 .LE. 0 ) GO TO 140	178
	CALL RNDX (8)	179
	ORPB=ORM+RXD(1)*ORS	180
	ORYB=ORM+RXD(2)*ORS	181
	ORPC=ORM+RXD(3)*ORS	182
	ORYC=ORM+RXD(4)*ORS	183
	TPPB=TPM+RXD(5)*TPS	184
	TPYB=TPM+RXD(6)*TPS	185
	TPPC=TPM+RXD(7)*TPS	186
	TPYC=TPM+RXD(8)*TPS	187
	IF (ORPB-1. .LE. 0 ) GO TO 70	188
	CALL OURF (TPPB,ORPB,PBFCT)	189
	GO TO 80	190
	70 PBFCT=0.0	191
	80 IF (ORPC-1.0 .LE. 0 ) GO TO 90	192
	CALL OURF (TPPC,ORPC,PCFCT)	193
	GO TO 100	194
	90 PCFCT=0.0	195
	100 IF (ORYB-1.0 .LE. 0 ) GO TO 110	196
	CALL OURF (TPYB,ORYB,YBFCT)	197
	GO TO 120	198
	110 YBFCT=0.0	199
	120 IF (ORYC-1.0 .LE. 0 ) GO TO 130	200
	CALL OURF (TPYC,ORYC,YCFCT)	201
	GO TO 140	202
	130 YCFCT=0.0	203
	140 CALL RNDX (1)	204

C	CALCULATE ADDITIONAL CONTROL MOTOR TURN-OFF DELAY DUE TO	205
C	STRUCTURAL FLEXIBILITY	206
	T2FLX=T2FM+RXD(1)*T2FS	207
C	COMPUTE BOOST PHASE INITIAL CONDITIONS, ET, DISTURBANCES	208
	CALL RNDX (16)	209
	DO 150 J=1,12	210
150	BT(J)=B(2*J-1)+RXD(J)*B(2*J)	211
	BT(13)=B(25)*RXD(13)+1.	212
	BT(14)=B(26)*RXD(14)+1.	213
	SUP=B(27)+RXD(15)*B(28)	214
	SUY=B(29)+RXD(16)*B(30)	215
C	CALCULATE WIND DIRECTION	216
	DW=BT(12)/57.3	217
	BT(3)=B(5)+B(6)*(RXD(1)*A(2)+RXD(3)*SQRT((A(1)-1.)*(1.-A(2)*A(2)))/	218
	1(A(1)-2.)))	219
	BT(4)=B(7)+B(8)*(RXD(2)*A(3)+RXD(4)*SQRT((A(1)-1.)*(1.-A(3)*A(3)))/	220
	1(A(1)-2.)))	221
	CALL RNDX (1)	222
	QRD=1.+RXD(1)*QFRAC	223
C	SELECT CONTROL SYSTEM RANDOM VARIABLES	224
	CALL RNDX (16)	225
	DO 160 J=1,8	226
	PC(J)=C(2*J-1)+RXD(J)*C(2*J)	227
160	YC(J)=C(2*J-1)+RXD(J+8)*C(2*J)	228
	CALL RNDX (7)	229
	DO 170 J=1,7	230
170	RC(J)=C(2*J+15)+RXD(J)*C(2*J+16)	231
C	TEST FOR STAGE OPTION 2-NO COAST CONTROL 3-COAST CONTROL	232
	IF (IO(2)-3 .LT. 0 ) GO TO 190	233
C	CALCULATE RANDOM CONTROL SYSTEM CHARACTERISTICS FOR COAST WITH	234
C	SEPARATE COAST SYSTEM USING YAW-ROLL MIXING	235
	CALL RNDX (10)	236
	DO 180 J=1,4	237
	PDC(J)=D(2*J-1)+RXD(J)*D(2*J)	238

180	PDC(J+4)=D(2*J+7)+RXD(J+4)*D(2*J+8)	239
	PDC(9)=D(1)+RXD(9)*D(2)	240
	PDC(10)=D(17)+RXD(10)*D(18)	241
	IF (IO(7)-1 .LT. 0 ) GO TO 190	242
C	COMPUTE COAST CONTROL VARIABLES WITHOUT YAW-ROLL MIXING	243
	CALL RNDX (3)	244
	YCF1=D(3)+RXD(1)*D(4)	245
	YCT1=D(5)+RXD(2)*D(6)	246
	YCT2=D(7)+RXD(3)*D(8)	247
C	COMPUTE ROLL TORQUES IMPULSE, CONTROL MOTOR TIME DELAYS,CONTROL	248
C	ACCELERATIONS AT IGNITION	249
190	RTI=ABS(BT(10))*12./A(7)	250
	T1P=PC(1)+PC(2)+PC(3)	251
	T2P=PC(1)+PC(2)+PC(4)	252
	T1Y=YC(1)+YC(2)+YC(3)	253
	T2Y=YC(1)+YC(2)+YC(4)	254
	THEDDA=PC(8)*((A(4)-TABL1(3)*BT(14))*A(8)+A(9)*A(5))/(12.*TABL1(2)	255
	1*BT(13))	256
	PSDDA=THEDDA*YC(8)/PC(8)	257
C	COMPUTE CAPTURE MANUEVER IMPULSE	258
	CAPIMP=PC(8)*(2.*T2P+ABS((BT(6)+2.*(BT(7)-PC(6))/PC(5))/(57.3*THED	259
	1DA)))+YC(8)*(2.*T2Y+ABS((BT(8)+2.*(BT(9)-YC(6))/YC(5))/(57.3*PSDDA	260
	2)))	261
	BIMP=0.	262
	THETP=0.0	263
	THETY=0.0	264
	CALL RNDX (3)	265
	VEL1=GAMEI*TBLS(2)*RXD(1)	266
	VEL2=ZEI*TBLS(2)*RXD(2)	267
	WINDEX=RXD(3)	268
	NER1=0	269
	NRR1=0	270
	NERC=0	271
C		272

C	CALCULATE IMPULSE IN PITCH AND YAW DURING BOOST PHASE	273
C		274
	DELTA=DELT1	275
	DO 300 J=1,NTOT	276
	IF(J.GT.NTB) DELTA=DELT2	277
	TA=TA1(J)	278
	H=HX(J)	279
	TC=TCX(J)	280
	U=UXX(J)	281
	GAMP=GAP(J)	282
	ZP=ZPX(J)	283
	BETPR=PSX(J)	284
	CTHX=THX(J)/BT(13)	285
	UV=UWMX(J)+WINDEX*VWSX(J)	286
	SGAMP=SIN(GAMP)	287
	CGAMP=COS(GAMP)	288
	UWCSDZ=UV*COS(DW-ZP)	289
	XNUM1=UWCSDZ*SGAMP	290
	XNUM2=UV*SIN(DW-ZP)	291
	XDEN1=U+UWCSDZ*CGAMP	292
	QWDFAC=QRD*(XDEN1*2./U+(UV/U)**2-1.)	293
	XKA=QWDFAC*X1KA(J)/BT(13)	294
	XKB=X1KB(J)/BT(13)	295
C	COMPUTE THRUST MISALIGNMENT	296
	ETPA=(BT(1)+BT(3)*TA)/57.3	297
	ETYA=(BT(2)+BT(4)*TA)/57.3	298
	THEDDA=PC(8)*CTHX	299
	PSDDA=THEDDA*YC(8)/PC(8)	300
C	COMPUTE ANGLES OF ATTACK IN PITCH AND YAW	301
	GAME1=VEL1/U	302
	ZE1=VEL2/U	303
C	CALCULATE ALPHA DUE TO WINDS	304
	ALPHW=(XNUM1/XDEN1)	305
C	CALCULATE BETA DUE TO WINDS	306

	BETAU=(XNUM2/XDEN1)	307
	ALPHP=TC-GAMP-GAME1+ALPHW	308
	BETAP=BETPR+BETAU+ZE1	309
C	CALCULATE PITCH AND YAW ACCEL DUE TO THRUST MISALIGNMENT , AERO	310
C	AND CG OFF-SET	311
	TOWI=TOW(J)/(XINER(J)*BT(13))	312
	THETP=XKA*ALPHP+XKB*ETPA+SUP*TOWI	313
	THETY=-XKA*BETAP+XKB*ETYA+SUY*TOWI	314
C	PICK DEADBAND SIDE AND ADD DEADBAND TO ANGLE OF ATTACK	315
	IF (THETP) 210,220,200	316
C	COMPUTE CROSS TRACK VELOCITY ERROR UPDATE	317
200	VEL1=VEL1+VELX(J)	318
	GAME=VEL1/U	319
	DALP=C(11)/57.3-(GAME-GAME1)/2.	320
	DADBP=DALP*XKA	321
	THETP=THETP+DADBP	322
	GO TO 220	323
210	VEL1=VEL1-VELX(J)	324
	GAME=VEL1/U	325
	DALP=-C(11)/57.3-(GAME-GAME1)/2.	326
	DADBP=DALP*XKA	327
	THETP=THETP+DADBP	328
220	IF (THETY) 240,250,230	329
230	VEL2=VEL2+VELX(J)	330
	ZE=VEL2/U	331
	DBET=-C(11)/57.3+(ZE-ZE1)/2.	332
	DADBY=-DBET*XKA	333
	THETY=THETY+DADBY	334
	GO TO 250	335
240	VEL2=VEL2-VELX(J)	336
	ZE=VEL2/U	337
	DBET=+C(11)/57.3+(ZE-ZE1)/2.	338
	DADBY=-DBET*XKA	339
	THETY=THETY+DADBY	340

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C      CALL SUBROUTINE FOR COMPUTING MINIMUM DISTURBING ACCELERATION FOR 341
C      ONE SIDED LIMIT CYCLE 342
250    CALL THEMIN (THEDDA,PC(5),PC(6),PC(7),T1P,T2P,THMIN) 343
      IF (ABS(THETP)-THMIN .GE. 0 ) GO TO 260 344
      CALL CYCLE (THEDDA,PC(5),PC(6),PC(7),T1P,T2P,DCP,AP,NERR1,PBFCT) 345
      GO TO 270 346
C      COMPUTE DUTY CYCLE AND INCREMENTAL IMPULSE 347
260    DCP=ABS(THETP/THEDDA) 348
270    DPI=DCP*PC(8)*DELTA 349
      CALL THEMIN (PSDDA,YC(5),YC(6),YC(7),T1Y,T2Y,THMIN) 350
      IF (ABS(THETY)-THMIN .GE. 0 ) GO TO 280 351
      CALL CYCLE (PSDDA,YC(5),YC(6),YC(7),T1Y,T2Y,DCY,AY,NERR1,YBFCT) 352
      GO TO 290 353
280    DCY=ABS(THETY/PSDDA) 354
290    DYI=DCY*YC(8)*DELTA 355
C      COMPUTE ROLL IMPULSE DUE TO CG OFFSET 356
      THXW=THX(J)*WGHT(J) 357
      TWLTLP=X1KB(J)/THXW 358
      TWWLP=TOW(J)/(THXW*XINER(J)) 359
      CNAWL=QWDFAC*X1KA(J)/THXW 360
      ALP=DALP+ALPHP 361
      BET=DBET+BETAP 362
      RM=TOW(J)*(SUP*ETYA-SUY*ETPA)+QWDFAC*CNASQ(J)*(SUY*ALP+
1    SUP*BET)/WGHT(J)+SUY*(TWLTLP*ETPA+TWWLP*SUP+
2    CNAWL*ALP)-SUP*(TWLTLP*ETYA+TWWLP*SUY-CNAWL*BET) 365
C      COMPUTE INCREMENTAL ROLL IMPULSE 366
      RIMP=12.*ABS(RM)*DELTA/A(7) 367
300    BIMP=BIMP+ABS(DPI)+ABS(DYI)+RIMP 368
C      COMPUTE TOTAL BOOST IMPULSE AND FUEL CONSUMPTION 369
      BIMP=(BIMP+CAPIMP)*(1.+(A(5)*A(8)*ABS(BT(11)))/(57.3*A(7)))+RTI 370
      WBOOST(ITER)=BIMP/BT(5) 371
      SWB=SWB+WBOOST(ITER) 372
C      COMPUTE LIMIT CYCLE FUEL CONSUMPTION DURING COAST WITH FILTER 373
C      IN USING BOOST CONTROL SYSTEM 374

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    THEDDA=PC(8)*((A(4)-BT(14)*TABL1(9))*A(8)+A(5)*A(9))/(12.*TABL1(8)375
1*BT(13)) 376
    PSDDA=THEDDA*YC(8)/PC(8) 377
    PHIDD=RC(7)*A(7)/(6.*A(16)) 378
    CALL CYCLE (THEDDA,PC(5),PC(6),PC(7),T1P,T2P,DCP,AP,NERR1,PBFCT) 379
    NER1=NER1+NERR1 380
    CALL CYCLE (PSDDA,YC(5),YC(6),YC(7),T1Y,T2Y,DCY,AY,NERR1,YBFCT) 381
    NER1=NER1+NERR1 382
    T1R=RC(1)+RC(2) 383
    T2R=RC(1)+RC(3) 384
    CALL CYCLE (PHIDD,RC(4),RC(5),RC(6),T1R,T2R,DCR,AR,NERR1,0.) 385
    NRR1=NRR1+NERR1 386
C    COMPUTE CONTROL FUEL FLOW RATE LIMIT CYCLE WITH BOOST CONTROLS 387
    WDFILT=(DCP*PC(8)+DCY*YC(8)+DCR*RC(7)*2.)/BT(5) 388
    TTO=TBO-TWEB 389
C    TEST FOR COAST FILTER OPTION 1-COAST FILTER OUT 2-COAST FILTER IN 390
    IF (IO(4)-2 .GE. 0 ) GO TO 420 391
C    COMPUTE FUEL WITH FILTER IN COAST FOR OPTION WITH FILTER SWITCHED 392
C    OUT DURING COAST 393
    DELT=A(10)-TBO 394
    WFILT=WDFILT*DELT 395
    GO TO 530 396
C    TEST FOR STAGE OPTION 2-NO COAST CONTROL 3-COAST CONTROL 397
420 IF (IO(2)-3 .GE. 0 ) GO TO 490 398
C    BOOST AND COAST CONTROL SYSTEM IS THE SAME 399
C    TEST FOR COAST OPTION 1-COAST TIME 2-COAST FUEL 400
    IF (IO(3)-2 .GE. 0 ) GO TO 460 401
C    STAGE 2 COAST TIME - FILTER IN 402
    TCOAST(ITER)=(A(12)-WBOOST(ITER))/WDFILT 403
    STC=STC+TCOAST(ITER) 404
C    TEST FOR PRINT OPTION 1-INDIVIDUAL SAMPLE DATA, 2-ONLY STATISTICS405
    IF (IO(1)-2 .GE. 0 ) GO TO 600 406
430 IF (NPK1 .NE. 0 ) GO TO 450 407
440 NPAGE=NPAGE+1 408

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	CALL PAGEHD (NRUN,NPAGE,NLINE)	409
	WRITE( 6,980)	410
	WRITE( 6,1010)	411
	NLINE=NLINE+6	412
	NPK1=1	413
450	IF (NLINE+3-62 .GT. 0 ) GO TO 440	414
	WRITE( 6,1000) ITER,CAPIMP,RTI,BIMP,TWEB,TTO,WBOOST(ITER),BT(5)	415
	WRITE( 6,1020) TCOAST(ITER),WDFILT,NER1,NRR1	416
	NLINE=NLINE+3	417
	GO TO 600	418
C	STAGE 2 COAST FUEL - FILTER IN	419
460	WCOAS(ITER)=A(11)*WDFILT	420
	SWC=SWC+WCOAS(ITER)	421
	WTOT(ITER)=WBOOST(ITER)+WCOAS(ITER)	422
	SWT=SWT+WTOT(ITER)	423
C	TEST PRINT OPTION 1-INDIVIDUAL SAMPLE DATA, 2-ONLY STATISTICAL	424
	IF (IO(1)-2 .GE. 0 ) GO TO 600	425
	IF (NPK1 .NE. 0 ) GO TO 480	426
470	NPAGE=NPAGE+1	427
	CALL PAGEHD (NRUN,NPAGE,NLINE)	428
	WRITE( 6,980)	429
	WRITE( 6,1030)	430
	NLINE=NLINE+6	431
	NPK1=1	432
480	IF (NLINE+3-62 .GT. 0 ) GO TO 470	433
	WRITE( 6,1000) ITER,CAPIMP,RTI,BIMP,TWEB,TTO,WBOOST(ITER),BT(5)	434
	WRITE( 6,1040) WCOAS(ITER),WDFILT,NER1,NRR1,WTOT(ITER)	435
	NLINE=NLINE+3	436
	GO TO 600	437
C	SEPARATE COAST CONTROL IO(2)=3	438
C	TEST FOR COAST OPTION 1-COAST TIME 2-COAST FUEL AND RETRO TIME	439
490	IF (IO(3)-2 .GE. 0 ) GO TO 500	440
C	COMPUTE STAGE 3 COAST TIME - FILTER IN	441
	TCOAST(ITER)=(A(12)-WBOOST(ITER)-2.*(PC(8)+YC(8)+RC(7))*TRETRO/RET	442



	1RSI)/WDFILT	443
	STC=STC+TCOAST(ITER)	444
C	TEST PRINT OPTION 1-INDIVIDUAL SAMPLE DATA, 2-ONLY STATISTICAL	445
	IF(IO(1)) 430,600,600	446
C	COMPUTE STAGE 3 COAST FUEL, RETRO TIME AND TOTAL FUEL FILTER IN	447
500	WCOAS(ITER)=A(11)*WDFILT	448
	WRETRO=A(12)-WBOOST(ITER)-WCOAS(ITER)	449
	TRET(ITER)=WRETRO*RETRSI/(2.*(PC(8)+YC(8)+RC(7)))	450
	SWC=SWC+WCOAS(ITER)	451
	STR=STR+TRET(ITER)	452
	WTOT(ITER)=A(12)-WRETRO*(1.-TRETRO/TRET(ITER))	453
	SWT=SWT+WTOT(ITER)	454
C	TEST PRINT OPTION 1-INDIVIDUAL SAMPLE DATA 2-ONLY STATISTICAL	455
	IF (IO(1)-2 .GE. 0 ) GO TO 600	456
	IF (NPK1 .NE. 0 ) GO TO 520	457
510	NPAGE=NPAGE+1	458
	CALL PAGEHD (NRUN,NPAGE,NLINE)	459
	WRITE( 6,980)	460
	WRITE( 6,1030)	461
	NLINE=NLINE+6	462
	NPK1=1	463
520	IF (NLINE+3-62 .GT. 0 ) GO TO 510	464
	WRITE( 6,1000) ITER,CAPIMP,RTI,BIMP,TWEB,TTO,WBOOST(ITER),BT(5)	465
	WRITE( 6,1040) WCOAS(ITER),WDFILT,NER1,NRR1,WTOT(ITER)	466
	NLINE=NLINE+3	467
	GO TO 600	468
C	FILTER OUT COAST OPTION	469
C	TEST FOR STAGE OPTION 2-NO COAST CONTROL 3-COAST CONTROL	470
530	IF (IO(2)-3 .GE. 0 ) GO TO 550	471
C	WITH BOOST CONTROL, FILTER OUT IN COAST	472
	T1P=PC(2)+PC(3)	473
	T2P=PC(2)+PC(4)+T2FLX	474
	T1Y=YC(2)+YC(3)	475
	T2Y=YC(2)+YC(4)+T2FLX	476

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CALL CYCLE (THEDDA,PC(5),PC(6),PC(7),T1P,T2P,DCP,AT,NERR1,PCFCT) 477
NERC=NERC+NERR1 478
CALL CYCLE (PSDDA,YC(5),YC(6),YC(7),T1Y,T2Y,DCY,AT,NERR1,YCFCT) 479
NERC=NERC+NERR1 480
WDCST=(DCR*RC(7)*2.+DCP*PC(8)+DCY*YC(8))/BT(5) 481
C TEST FOR COAST OPTION 1-COAST TIME 2-COAST FUEL AND RETRO TIME 482
IF (IO(3)-2 .GE. 0 ) GO TO 540 483
C COMPUTE COAST TIME 484
TCOAST(ITER)=DELT+(A(12)-WBOOST(ITER)-WFILT)/WDCST 485
STC=STC+TCOAST(ITER) 486
GO TO 600 487
C COMPUTE COAST FUEL AND BOOST+COAST FUEL 488
C COAST TIME IS ONLY PORTION WITH FILTER SWITCHED OUT; COAST FUEL 489
C INCLUDES FILTER IN AND FILTER OUT COAST TIMES 490
540 WCOAS(ITER)=A(11)*WDCST+WFILT 491
SWC=SWC+WCOAS(ITER) 492
WTOT(ITER)=WBOOST(ITER)+WCOAS(ITER) 493
SWT=SWT+WTOT(ITER) 494
GO TO 600 495
C STAGE 3 OPTION 496
C SEPARATE COAST CONTROL FILTER OUT IN COAST AND YAW-ROLL MIXING 497
C 2 ROLL MOTORS FOR YAW; 2 ROLL MOTORS FOR ROLL 498
550 THEDDA=THEDDA*PDC(2)/PC(8) 499
PSDDA=PSDDA*2.*PDC(6)/YC(8) 500
PHIDD=PHIDD*PDC(6)/RC(7) 501
T1P=PC(2)+PDC(3) 502
T2P=PC(2)+PDC(4)+T2FLX 503
T1Y=YC(2)+PDC(7) 504
T2Y=YC(2)+PDC(8)+T2FLX 505
T1R=RC(1)+PDC(7) 506
T2R=RC(1)+PDC(8) 507
C COMPUTE PITCH, YAW, ROLL TORQUEING AND DEADBAND REDUCTION FUEL 508
PRTRW=(PDC(2)*(2.*T2P+ABS((PTRC+57.3*AP+2.*(PC(6)-PDC(1))/PC(5)))/(509
157.3*THEDDA)))) 510

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      YRTRW=2.*PDC(6)*(2.*T2Y+ABS((YTRC+57.3*AY+2.*(YC(6)-PDC(9))/YC(5))511
1/(57.3*PSDDA)))512
      RRTRW=2.*PDC(6)*(2.*T2R+ABS((57.3*AR+2.*(RC(5)-PDC(5))/RC(4))/(57.513
13*PHIDD)))514
C      TEST COAST SYSTEM IO(7)= 0 YAW-ROLL MIXING,  -1 NO MIXING515
      IF (IO(7)-1 .LT. 0 ) GO TO 560516
C      NO YAW-ROLL MIXING, SEPARATE PITCH AND YAW MOTORS517
      PSDDA=PSDDA*YCF1/(2.*PDC(6))518
      T1Y=YC(2)+YCT1519
      T2Y=YC(2)+YCT2+T2FLX520
      YRTRW=YCF1*(2.*T2Y+ABS((YTRC+57.3*AY+2.*(YC(6)-PDC(9))/YC(5))/(57.521
13*PSDDA)))522
C      COMPUTE FUEL REQUIRED FOR DEADBAND REDUCTION AND TORQUEING523
560 TRDRW=(PRTRW+YRTRW+RRTRW)/PDC(10)524
      CALL CYCLE (THEDDA,PC(5),PDC(1),PC(7),T1P,T2P,DCP,AT,NERR1,PCFCT)525
      NERC=NERC+NERR1526
      CALL CYCLE (PSDDA,YC(5),PDC(9),YC(7),T1Y,T2Y,DCY,AT,NERR1,YCFCT)527
      NERC=NERC+NERR1528
      CALL CYCLE (PHIDD,RC(4),PDC(5),RC(6),T1R,T2R,DCR,AT,NERR1,0.0)529
      NERC=NERC+NERR1530
C      TEST FOR COAST CONTROL SYSTEM 0=YAW-ROLL MIXING, 1= NO MIXING531
      IF (IO(7)-1 .GE. 0 ) GO TO 570532
C      YAW-ROLL MIXING533
      WDCST=(PDC(2)*DCP+2.*PDC(6)*(DCY+DCR))/PDC(10)534
      GO TO 580535
570 WDCST=(PDC(2)*DCP+2.*PDC(6)*DCR+YCF1*DCY)/PDC(10)536
C      TEST FOR COAST OPTION 1-COAST TIME 2-COAST FUEL AND RETRO TIME537
580 IF (IO(3)-2 .GE. 0 ) GO TO 590538
C      COAST TIME OPTION539
      TCOAST(ITER)=DELT+(A(12)-WBOOST(ITER)-WFILT-TRDRW-(PC(8)+YC(8)+RC(540
17))*2.*TRETRO/RETRSI)/WDCST541
      STC=STC+TCOAST(ITER)542
      GO TO 600543
C      STAGE 3 COAST FUEL, RETRO TIME, TOTAL FUEL WITH INPUT RETRO TIME544

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590	WCOAS(ITER)=A(11)*WDCST+WFILT	545
	SWC=SWC+WCOAS(ITER)	546
	WRETRO=A(12)-WBOOST(ITER)-TRDRW-WCOAS(ITER)	547
	TRET(ITER)=WRETRO*RETRSI/(2.*(PC(8)+YC(8)+RC(7)))	548
	STR=STR+TRET(ITER)	549
	WTOT(ITER)=A(12)-WRETRO*(1.-TRETRO/TRET(ITER))	550
	SWT=SWT+WTOT(ITER)	551
C	UPDATE COUNTER ON NUMBER OF DEADBAND OVERSHOOT CASES	552
600	IF (NER1-1 .LT. 0 ) GO TO 610	553
	MER1=MER1+1	554
610	IF (NRR1-1 .LT. 0 ) GO TO 620	555
	MRER1=MRER1+1	556
620	IF (NERC-1 .LT. 0 ) GO TO 630	557
	MERC=MERC+1	558
C	TEST FOR COAST FILTER OPTION 1-COAST FILTER OUT 2-COAST FILTER IN	559
630	IF (IO(4)-2 .GE. 0 ) GO TO 750	560
C	TEST PRINT OPTION 1-INDIVIDUAL SAMPLE RESULTS, 2-ONLY STATISTICAL	561
	IF (IO(1)-2 .GE. 0 ) GO TO 750	562
C	TEST FOR STAGE OPTION 2-BOOST CONTROL COAST 3-COAST CONTROL	563
	IF (IO(2)-3 .GE. 0 ) GO TO 690	564
C	TEST FOR COAST OPTION 1-COAST TIME 2-COAST FUEL AND RETRO TIME	565
	IF (IO(3)-2 .GE. 0 ) GO TO 660	566
	IF (NPK1 .NE. 0 ) GO TO 650	567
C	PRINT COAST TIME	568
640	NPAGE=NPAGE+1	569
	CALL PAGEHD (NRUN,NPAGE,NLINE)	570
	WRITE( 6,980)	571
	WRITE( 6,1050)	572
	NLINE=NLINE+6	573
	NPK1=1	574
650	IF (NLINE+3-62 .GT. 0 ) GO TO 640	575
	WRITE( 6,1000) ITER,CAPIMP,RTI,BIMP,TWEB,TTO,WBOOST(ITER),BT(5)	576
	WRITE( 6,1060) TCOAST(ITER),WDFILT,WDCST,NER1,NRR1	577
	NLINE=NLINE+3	578

	GO TO 750	579
C	PRINT COAST FUEL AND RETRO TIME	580
660	IF (NPK1 .NE. 0 ) GO TO 680	581
670	NPAGE=NPAGE+1	582
	CALL PAGEHD (NRUN,NPAGE,NLINE)	583
	WRITE( 6,980)	584
	WRITE( 6,1070)	585
	NLINE=NLINE+6	586
	NPK1=1	587
680	IF (NLINE+3-62 .GT. 0 ) GO TO 670	588
	WRITE( 6,1000) ITER,CAPIMP,RTI,BIMP,TWEB,TTO,WBOOST(ITER),BT(5)	589
	WRITE( 6,1080) WCOAS(ITER),WDFILT,WDCST,NER1,NRR1,NERC,WTOT(ITER)	590
	NLINE=NLINE+3	591
	GO TO 750	592
C	TEST FOR COAST OPTION 1-COAST TIME 2-COAST FUEL AND RETRO TIME	593
690	IF (IO(3)-2 .GE. 0 ) GO TO 720	594
C	PRINT COAST TIME	595
	IF (NPK1 .NE. 0 ) GO TO 710	596
700	NPAGE=NPAGE+1	597
	CALL PAGEHD (NRUN,NPAGE,NLINE)	598
	WRITE( 6,980)	599
	WRITE( 6,1090)	600
	NLINE=NLINE+6	601
	NPK1=1	602
710	IF (NLINE+3-62 .GT. 0 ) GO TO 700	603
	WRITE( 6,1000) ITER,CAPIMP,RTI,BIMP,TWEB,TTO,WBOOST(ITER),BT(5)	604
	WRITE( 6,1100) TCOAST(ITER),WDFILT,TRDRW,WDCST,NER1,NRR1,NERC	605
	NLINE=NLINE+3	606
	GO TO 750	607
C	PRINT COAST FUEL AND RETRO TIME	608
720	IF (NPK1 .NE. 0 ) GO TO 740	609
730	NPAGE=NPAGE+1	610
	CALL PAGEHD (NRUN,NPAGE,NLINE)	611
	WRITE( 6,980)	612

	WRITE( 6,1110)	613
	NLINE=NLINE+6	614
	NPK1=1	615
740	IF (NLINE+3-62 .GT. 0 ) GO TO 730	616
	WRITE( 6,1000) ITER,CAPIMP,RTI,BIMP,TWEB,TTO,WBOOST(ITER),BT(5)	617
	WRITE( 6,1120) WCOAS(ITER),WDFILT,TRDRW,WDCST,TRET(ITER),NER1,NRR1	618
	1,NERC,WTOT(ITER)	619
	NLINE=NLINE+3	620
750	CONTINUE	621
C		622
C	END OF INDIVIDUAL SAMPLE CALCULATION LOOP	623
C		624
C	BEGIN PART 2 STATISTICAL ANALYSIS	625
	AVI=IT	626
	VI=AVI+1.	627
	VIB=AVI-1.	628
	WBMEAN=SWB/AVI	629
C	TEST FOR COAST OPTION 1-COAST TIME 2-COAST FUEL AND RETRO TIME	630
	IF (IO(3)-2 .GE. 0 ) GO TO 790	631
C	COAST TIME OPTION	632
	TCMEAN=STC/AVI	633
C	CALL SUBROUTINE FOR REARRANGING ARRAYS	634
	CALL ASCEND (IT,WBOOST,0)	635
	CALL ASCEND (IT,TCOAST,1)	636
	SDXWB=0.	637
	SDXTC=0.	638
C	COMPUTE DISCRETE SAMPLE PROBABILITY LEVEL,SUM VALUES AND SQUARES	639
	DO 780 KAB=1,IT	640
	XKAB=KAB	641
	PROB=XKAB/VI	642
	DXWB=(WBMEAN-WBOOST(KAB))*2	643
	DXTC=(TCMEAN-TCOAST(KAB))*2	644
	SDXWB=SDXWB+DXWB	645
	SDXTC=SDXTC+DXTC	646

C	PRINT ELEMENTS OF REARRANGED ARRAY AS COMPUTED	647
	IF (NPK2 .NE. 0 ) GO TO 770	648
760	NPAGE=NPAGE+1	649
	CALL PAGEHD (NRUN,NPAGE,NLINE)	650
	WRITE( 6,1130)	651
	NLINE=NLINE+4	652
	NPK2=1	653
770	IF (NLINE+1-62 .GT. 0 ) GO TO 760	654
	WRITE( 6,1140) PROB,WBOOST(KAB),TCOAST(KAB)	655
	NLINE=NLINE+1	656
780	CONTINUE	657
C	PRINT MEAN,SIGMA,LAST RANDOM SEQUENCE INTEGER,NO. OF DEADBAND OVER	658
C	SHOOT CASES	659
	SIGB=SQRT(SDXWB/VIB)	660
	SIGT=SQRT(SDXTC/VIB)	661
	NPAGE=NPAGE+1	662
	CALL PAGEHD (NRUN,NPAGE,NLINE)	663
	WRITE( 6,1150)	664
	WRITE( 6,1160) WBMEAN,TCMEAN	665
	WRITE( 6,1170) SIGB,SIGT	666
C	FIND LAST RANDOM SEQUENCE INTEGER,CDC RANF RANDOM NUMBER GENERATOR	667
	CALL RANGET (K)	668
	WRITE( 6,1180) K	669
	WRITE( 6,1190)	670
	WRITE( 6,1200) MER1	671
	WRITE( 6,1210) MRER1	672
	WRITE( 6,1220) MERC	673
	GO TO 10	674
C	OPTION FOR FUEL CONSUMPTION	675
790	WCMEAN=SWC/AVI	676
	WTOTM=SWT/AVI	677
C	TEST FOR STAGE OPTION 2-COAST WITH CONTROL 3-COAST CONTROL	678
	IF (IO(2)-3 .LT. 0 ) GO TO 870	679
C	SEPARATE COAST CONTROL OPTION	680

	TRETM=STR/AVI	681
	CALL ASCEND (IT,WBOOST,0)	682
	CALL ASCEND (IT,WCOAS,0)	683
	CALL ASCEND (IT,WTOT,0)	684
	CALL ASCEND (IT,TRET,1)	685
	SDXWB=0.	686
	SDXFC=0.	687
	SDXWT=0.	688
	SDXRT=0.	689
C	CALCULATE PROBABILITIES OF FUEL CONSUMPTION AND RETRO TIME	690
	DO 820 KAB=1,IT	691
	XKAB=KAB	692
	PROB=XKAB/UI	693
	DXWB=(WBMEAN-WBOOST(KAB))*2	694
	DXFC=(WCMEAN-WCOAS(KAB))*2	695
	DXWT=(WTOTM-WTOT(KAB))*2	696
	DXRT=(TRETM-TRET(KAB))*2	697
	SDXWB=SDXWB+DXWB	698
	SDXFC=SDXFC+DXFC	699
	SDXWT=SDXWT+DXWT	700
	SDXRT=SDXRT+DXRT	701
C	PRINT ELEMENTS OF REARRANGED ARRAY AS COMPUTED	702
	IF (NPK3 .NE. 0 ) GO TO 810	703
800	NPAGE=NPAGE+1	704
	CALL PAGEHD (NRUN,NPAGE,NLINE)	705
	WRITE( 6,1230)	706
	NLINE=NLINE+4	707
	NPK3=1	708
810	IF (NLINE+1-62 .GT. 0 ) GO TO 800	709
	WRITE( 6,1240) PROB,WBOOST(KAB),WCOAS(KAB),TRET(KAB),WTOT(KAB)	710
	NLINE=NLINE+1	711
820	CONTINUE	712
	SIGB=SQRT(SDXWB/UIB)	713
	SIGWC=SQRT(SDXFC/UIB)	714



	SIGWT=SQRT(SDXWT/UIB)	715
	SIGRT=SQRT(SDXRT/UIB)	716
	IF (IT-100 .LT. 0 ) GO TO 850	717
	ANI=0.995*UI	718
	NI=ANI	719
	ANIP=NI	720
	IF (.5-(ANI-ANIP) .GT. 0 ) GO TO 840	721
	NI=NI+1	722
840	CONTINUE	723
C	COMPUTE UPPER 95% CONFIDENCE LEVEL ON 99.5% PROBABILITY LEVEL	724
	DEN=SQRT(1.-1.96*SQRT(2./(AUI-1.)))	725
	XK=1./DEN	726
	XWB95=WBMEAN+XK*(WBOOST(NI)-WBMEAN)	727
	XWC95=WCMEAN+XK*(WCOAS(NI)-WCMEAN)	728
	XWT95=WTOTM+XK*(WTOT(NI)-WTOTM)	729
	XRET95=TRETM+XK*(TRET(NI)-TRETM)	730
850	NPAGE=NPAGE+1	731
	CALL PAGEHD (NRUN,NPAGE,NLINE)	732
	WRITE( 6,1340)	733
	WRITE( 6,1350)	734
	WRITE( 6,1340)	735
	WRITE( 6,1250)	736
	WRITE( 6,1260) WBMEAN,WCMEAN,TRETM,WTOTM	737
	WRITE( 6,1270) SIGB,SIGWC,SIGRT,SIGWT	738
	IF (IT-100 .LT. 0 ) GO TO 860	739
	WRITE( 6,1310) XWB95,XWC95,XRET95,XWT95	740
860	CONTINUE	741
C	RETRIEVE LAST RANDOM SEQUENCE INTEGER	742
	CALL RANGET (K)	743
	WRITE( 6,1180) K	744
	WRITE( 6,1190)	745
	WRITE( 6,1200) MER1	746
	WRITE( 6,1210) MRER1	747
	WRITE( 6,1220) MERC	748

C	COMPUTE STATISTICS AND COMPARE WITH NORMAL, LOG-NORMAL, AND WEIBULL	749
C	STATISTICAL DISTRIBUTION FUNCTIONS	750
	CALL WBL (IT, WBOOST, NUMCHI, FWB)	751
	CALL WBL (IT, WCOAS, NUMCHI, FWC)	752
	CALL WBL (IT, WTOT, NUMCHI, FWT)	753
	WRITE( 6, 1400)	754
	WRITE( 6, 1410) ((FWB(J), FWC(J), FWT(J)), J=1, 4), FWB(9), FWC(9), FWT(9)	755
	1, FWB(18), FWC(18), FWT(18)	756
	WRITE( 6, 1420)	757
	WRITE( 6, 1410) ((FWB(J), FWC(J), FWT(J)), J=5, 8), FWB(10), FWC(10), FWT(10),	758
	FWB(19), FWC(19), FWT(19)	759
	WRITE( 6, 1430) ((FWB(J), FWC(J), FWT(J)), J=11, 17), FWB(20), FWC(20), FWT(20)	760
	1T(20)	761
C	TEST FOR HISTOGRAM OUTPUT OPTION IO(9)=0 HISTOGRAMS, -1 NONE	762
	IF (IO(9).EQ.1) GO TO 10	763
C	CALCULATE AND PLOT HISTOGRAMS	764
	NDX=30	765
C	COMPUTE RANGE OF VARIABLES AND PLOT HISTOGRAM FOR RETRO TIME	766
	CALL RANGE (TRET, IT, GREAT, SMALL, DX, NDX, ERRTB)	767
	IF (ERRTB .GT. 0 ) GO TO 950	768
	WRITE( 6, 1390)	769
	CALL HISTO (TRET, IT, GREAT, SMALL, DX)	770
	GO TO 950	771
C	STAGE 3- SEPARATE COAST CONTROL OPTION	772
870	CALL ASCEND (IT, WBOOST, 0)	773
	CALL ASCEND (IT, WCOAS, 0)	774
	CALL ASCEND (IT, WTOT, 0)	775
	SDXWB=0.	776
	SDXFC=0.	777
	SDXWT=0.	778
C	COMPUTE PROBABILITY DISTRIBUTION AND SUM OF SQUARES	779
	DO 900 KAB=1, IT	780
	XKAB=KAB	781
	PROB=XKAB/VI	782

	DXWB=(WBMEAN-WBOOST(KAB))*2	783
	DXFC=(WCMEAN-WCOAS(KAB))*2	784
	DXWT=(WTOTM-WTOT(KAB))*2	785
	SDXWB=SDXWB+DXWB	786
	SDXFC=SDXFC+DXFC	787
	SDXWT=SDXWT+DXWT	788
C	PRINT ELEMENTS OF REARRANGED ARRAY AS COMPUTED	789
	IF (NPK4 .NE. 0 ) GO TO 890	790
880	NPAGE=NPAGE+1	791
	CALL PAGEHD (NRUN,NPAGE,NLINE)	792
	WRITE( 6,1280)	793
	NLINE=NLINE+4	794
	NPK4=1	795
890	IF (NLINE+1-62 .GT. 0 ) GO TO 880	796
	WRITE( 6,1290) PROB,WBOOST(KAB),WCOAS(KAB),WTOT(KAB)	797
	NLINE=NLINE+1	798
900	CONTINUE	799
C	COMPUTE STANDARD DEVIATION	800
	SIGB=SQRT(SDXWB/VIB)	801
	SIGWC=SQRT(SDXFC/VIB)	802
	SIGWT=SQRT(SDXWT/VIB)	803
	IF (IT-100 .LT. 0 ) GO TO 930	804
	ANI=0.995*VI	805
	NI=ANI	806
	ANIP=NI	807
	IF (.5-(ANI-ANIP) .GT. 0 ) GO TO 920	808
	NI=NI+1	809
920	CONTINUE	810
C	COMPUTE UPPER 95% CONFIDENCE LEVEL, 99.5% PROBABILITY LEVEL	811
	DEN=SQRT(1.-1.96*SQRT(2./(AVI-1.)))	812
	XK=1./DEN	813
	XWB95=WBMEAN+XK*(WBOOST(NI)-WBMEAN)	814
	XWC95=WCMEAN+XK*(WCOAS(NI)-WCMEAN)	815
	XWT95=WTOTM+XK*(WTOT(NI)-WTOTM)	816

930	NPAGE=NPAGE+1	817
	CALL PAGEHD (NRUN,NPAGE,NLINE)	818
	WRITE( 6,1340)	819
	WRITE( 6,1350)	820
	WRITE( 6,1340)	821
	WRITE( 6,1300)	822
	WRITE( 6,1260) WBMEAN,WCMEAN,WTOTM	823
	WRITE( 6,1270) SIGB,SIGWC,SIGWT	824
	IF (IT-100 .LT. 0 ) GO TO 940	825
	WRITE( 6,1310) XWB95,XWC95,XWT95	826
940	CONTINUE	827
C	FIND LAST RANDOM SEQUENCE INTEGER	828
	CALL RANGET (K)	829
	WRITE( 6,1180) K	830
	WRITE( 6,1190)	831
	WRITE( 6,1200) MER1	832
	WRITE( 6,1210) MRER1	833
	WRITE( 6,1220) MERC	834
C	COMPUTE STATISTICAL PARAMETERS AND FIT TO NORMAL, LOG-NORMAL, AND	835
C	WEIBULL DISTRIBUTION FUNCTIONS	836
	CALL WBL (IT,WBOOST,NUMCHI,FWB)	837
	CALL WBL (IT,WCOAS,NUMCHI,FWC)	838
	CALL WBL (IT,WTOT,NUMCHI,FWT)	839
	WRITE( 6,1400)	840
	WRITE( 6,1410) ((FWB(J),FWC(J),FWT(J)),J=1,4),FWB(9),FWC(9),FWT(9)	841
	1,FWB(18),FWC(18),FWT(18)	842
	WRITE( 6,1420)	843
	WRITE( 6,1410) ((FWB(J),FWC(J),FWT(J)),J=5,8),FWB(10),FWC(10),FWT(844	
	110),FWB(19),FWC(19),FWT(19)	845
	WRITE( 6,1430) ((FWB(J),FWC(J),FWT(J)),J=11,17),FWB(20),FWC(20),FW	846
	1T(20)	847
C	TEST FOR HISTOGRAM OUTPUT IO(9)=0 GIVES HISTOGRAMS, -1 NONE	848
	IF (IO(9).EQ.1) GO TO 10	849
C	CALCULATE AND PLOT HISTOGRAMS OF BOOST, COAST, AND TOTAL FUEL	850

	NDX=30	851
950	CONTINUE	852
	CALL RANGE (WBOOST,IT,GREAT,SMALL,DX,NDX,ERRTB)	853
	IF (ERRTB .GT. 0 ) GO TO 960	854
	WRITE( 6,1360)	855
	CALL HISTO (WBOOST,IT,GREAT,SMALL,DX)	856
960	CALL RANGE (WCOAS,IT,GREAT,SMALL,DX,NDX,ERRTB)	857
	IF (ERRTB .GT. 0 ) GO TO 970	858
	WRITE( 6,1370)	859
	CALL HISTO (WCOAS,IT,GREAT,SMALL,DX)	860
970	CALL RANGE (WTOT,IT,GREAT,SMALL,DX,NDX,ERRTB)	861
	IF (ERRTB .GT. 0 ) GO TO 10	862
	WRITE( 6,1380)	863
	CALL HISTO (WTOT,IT,GREAT,SMALL,DX)	864
	GO TO 10	865
C		866
C	END OF MAIN ROUTINE ONLY FORMAT STATEMENT FOLLOW	867
C		868
980	FORMAT (/85H SMPL CAPT IMP ROLL TORQ BOOST IMP T(WEB)	869
	1 T(TO) BOOST FUEL ISP/8X,77H(LB-SEC) IMP(LB-SC) (LB-S	870
	2EC) (SEC) (SEC) (LBS) (SEC))	871
990	FORMAT (8F10.3)	872
1000	FORMAT (/I5,1P7E12.4)	873
1010	FORMAT (8X,44HCST TIME FLOW RATE NO. OF DB OVERSHOOTS,/10X,39874	874
	1H(SEC) FILTER IN BOOST P-Y ROLL)	875
1020	FORMAT (5X,1P2E12.4,I8,I12)	876
1030	FORMAT (8X,43HCST FUEL FLOW RATE NO. OF DB OVERSHOOTS,3X,10HT0877	877
	1TAL FUEL,/10X,40H(LBS) FILTER IN BOOST P-Y ROLL,7X,5H(L878	878
	2BS),/)	879
1040	FORMAT (5X,1P2E12.4,I8,I12,4X,1PE12.4)	880
1050	FORMAT (8X,55HCST TIME FLOW RATE FLOW RATE NO. OF DB OVERSHO881	881
	10TS,/10X,53H(SEC) FILTER IN COAST BOOST P-Y ROLL	882
	2,/)	883
1060	FORMAT (5X,1P3E12.4,I8,I12)	884

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1070 FORMAT (8X,66HCST FUEL FLOW RATE FLOW RATE NUMBER OF DEADB885
1AND OVERSHOOTS,4X,10HTOTAL FUEL,/,8X,78H(POUNDS) FILTER IN C886
2OAST BOOST P-Y ROLL COAST P-Y (LBS),/) 887
1080 FORMAT (5X,1P3E12.4,I8,2I12,4X,1PE12.4) 888
1090 FORMAT (8X,69HCST TIME FLOW RATE DB RED TORQ FLOW RATE NUM889
1BER OF OVERSHOOTS,/,7X,81H(SECONDS) FILTER IN FUEL(LBS) C0890
2AST BOOST P-Y ROLL COAST P-Y,/) 891
1100 FORMAT (5X,1P4E12.4,I8,2I12) 892
1110 FORMAT (8X,93HCST FUEL FLOW RATE DB RED TORQ FLOW RATE RETRO 893
1TIME NO. OF DB OVERSHOOTS TOTAL FUEL,/,8X,89H(POUNDS) FILTER894
2 IN FUEL(LBS) COAST (SEC) BOOST P-Y ROLL CST P-Y 895
3 (LBS),/) 896
1120 FORMAT (5X,1P5E12.4,I8,2I6,4X,1PE12.4) 897
1130 FORMAT (//5X,11HPROBABILITY,6X,10HBOOST FUEL,7X,10HCOAST TIME,/,23X898
1,8H(POUNDS),9X,9H(SECONDS),/) 899
1140 FORMAT (5X,F10.5,F16.3,F19.4) 900
1150 FORMAT (//22X,10HBOOST FUEL,7X,10HCOAST TIME) 901
1160 FORMAT (/5X,4HMEAN,11X,F11.3,F19.4) 902
1170 FORMAT (/5X,14HSTD. DEVIATION,F12.3,F19.4) 903
1180 FORMAT (//5X,42HFINAL VALUE OF RANDOM SEQUENCE INTEGER = ,I20) 904
1190 FORMAT (/5X,38HNO. OF SAMPLES WITH DEADBAND OVERSHOOT) 905
1200 FORMAT (/10X,25HBOOST(PITCH AND YAW) =,I8) 906
1210 FORMAT (/15X,20H(ROLL) =,I8) 907
1220 FORMAT (/10X,25HCOAST =,I8) 908
1230 FORMAT (/5X,11HPROBABILITY,6X,10HBOOST FUEL,5X,10HCOAST FUEL,5X,10909
1HRETRO TIME,6X,10HTOTAL FUEL,/,23X,8H(POUNDS),7X,8H(POUNDS),7X,9H(910
2SECONDS),7X,8H(POUNDS),/) 911
1240 FORMAT (5X,F10.5,F16.3,F15.3,F16.4,F15.3) 912
1250 FORMAT (22X,10HBOOST FUEL,5X,10HCOAST FUEL,5X,10HRETRO TIME,6X,10H913
1TOTAL FUEL) 914
1260 FORMAT (/5X,4HMEAN,11X,F11.3,F15.3,F16.4,F15.3) 915
1270 FORMAT (/5X,14HSTD. DEVIATION,F12.3,F15.3,F16.4,F15.3) 916
1280 FORMAT (/5X,11HPROBABILITY,6X,10HBOOST FUEL,5X,10HCOAST FUEL,6X,10917
1HTOTAL FUEL,/,23X,8H(POUNDS),7X,8H(POUNDS),8X,8H(POUNDS)) 918

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1290 FORMAT (5X,F10.5,F16.3,F16.4,F15.3) 919
1300 FORMAT (/22X,25HBOOST FUEL COAST FUEL,6X,10HTOTAL FUEL) 920
1310 FORMAT (/5X,*0.995 PROB*,5X,F11.3,F15.3,F16.4,F15.3,/,5X,*0.95 CON921
1FID*) 922
1320 FORMAT (I18) 923
1330 FORMAT (I1I5) 924
1340 FORMAT (//) 925
1350 FORMAT (72H 926
1 /72H 927
2 ) 928
1360 FORMAT (1H1,11X,*BOOST FUEL CONSUMPTION HISTOGRAM*,/) 929
1370 FORMAT (1H1,11X,*COAST FUEL CONSUMPTION HISTOGRAM*,/) 930
1380 FORMAT (1H1,11X,*TOTAL FUEL CONSUMPTION HISTOGRAM*,/) 931
1390 FORMAT (1H1,11X,*RETRO TIME HISTOGRAM*,/) 932
1400 FORMAT (1H1,5X,*DISTRIBUTION FUNCTION FIT*,/34X,*BOOST COAST 933
1 TOTAL*,/5X,*NORMAL DISTRIBUTION*,/) 934
1410 FORMAT (10X,*MEAN*,16X,3F10.3,/10X,*STANDARD DEV*,8X,3F10.3,/10X,*935
1SKEWNESS*,12X,3F10.3,/10X,*KURTOSIS*,12X,3F10.3,/10X,*0.995 PROB 0936
2.95 CONF*,3F10.3,/10X,*LEVEL OF SIGNIFICNCE*,3F10.3) 937
1420 FORMAT (/,5X,*LOG NORMAL DISTRIBUTION*,/6X,*(VALUES OF LOG)* ) 938
1430 FORMAT (/,5X,*WEIBULL DISTRIBUTION*,/10X,*PARAMETERS A*,8X,3F10.4,939
1/21X,*B*,8X,3F10.4,/21X,*C*,8X,3F10.4,/10X,*PROBABILITY 0.5000*,2X940
2,3F10.3,/22X,*0.9900 *,3F10.3,/22X,*0.9950 *,3F10.3,/22X,*0.9990941
3 *,3F10.3,/10X,*LEVEL OF SIGNIFICANCE*,3F10.3) 942
1440 FORMAT (3(E10.3)) 943
1450 FORMAT (E15.5) 944
1460 FORMAT (2(E15.5)) 945
1470 FORMAT (I5/(6F10.3)) 946
END 947

```

*DECK	ALTI	948
	SUBROUTINE ALTI (ALTO,UO,QO)	949
C	THIS SUBROUTINE COMPUTES THE ALTITUDE(ALTO) FROM THE	950
C	VELOCITY AND DYNAMIC PRESSURE USING THE ALTITUDE-DENSITY TABLE	951
	DIMENSION DUM(18)	952
	COMMON/DRH/RHO(18),MR	953
	MR=1	954
	RHI=ALOG(UO*UO/(2.*QO))	955
C	EXCHANGE THE ORDINATES AND ABSCISSAS IN THE ALTITUDE-DENSITY TABLE	956
	DO 10 J=1,18,2	957
	DUM(J)=RHO(J+1)	958
10	DUM(J+1)=RHO(J)	959
	CALL TBLU (18,ALTO,RHI,DUM,MR)	960
	RETURN	961
	END	962



*DECK ASCEND	963
SUBROUTINE ASCEND (L,VAL,M)	964
C SUBROUTINE FOR REARRANGING ARRAY IN ASCENDING ORDER	965
C OR DESCENDING ORDER IF M=1	966
DIMENSION VAL(1)	967
K=L-1	968
DO 40 J=1,K	969
KB=J+1	970
DO 40 JL=KB,L	971
IF(M) 10,10,20	972
10 IF (VAL(J)-VAL(JL) .LE. 0 ) GO TO 40	973
GO TO 30	974
20 IF(VAL(JL)-VAL(J).LE.0) GO TO 40	975
30 TEMP=VAL(J)	976
VAL(J)=VAL(JL)	977
VAL(JL)=TEMP	978
40 CONTINUE	979
RETURN	980
END	981

*DECK	CALCU	982
	SUBROUTINE CALCU	983
C	THIS SUBROUTINE COMPUTES THE STATE VARIABLES AND THE FIRST	984
C	DERIVATIVES FOR USE WITH THE RUNGE SUBROUTINE	985
	COMMON/DDI/TBL2(90),TBL3(90),NTHT,NWT,CDS,M2,M3,WBO	986
	COMMON/DDY/YDOT(4),Y(4),T,DT	987
	COMMON/DRH/RHO(18),MR	988
	DATA GO,RO,CON/32.174,20919668.,57.29577951/	989
	CALL TBLU (NTHT,TH,T,TBL2,M2)	990
	CALL TBLU (NWT,WT,T,TBL3,M3)	991
	ALT=Y(2)	992
	CALL TBLU (18,RHI,ALT,RHO,MR)	993
	Y(4)=0.5*Y(1)*Y(1)/EXP(RHI)	994
	G=GO/(1.+Y(2)/RO)**3	995
	GAMA=Y(3)/CON	996
	YDOT(1)=GO*(TH-CDS*Y(4))/(WT+WBO)-G*SIN(GAMA)	997
	YDOT(3)=-CON*(G*COS(GAMA))/Y(1)	998
	YDOT(2)=Y(1)*SIN(GAMA)	999
	RETURN	1000
	END	1001

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*DECK CHISQ                                1002
      SUBROUTINE CHISQ (N,A,CR,NG,AM,AS,WA,WB,WC,LD) 1003
C      THIS SUBROUTINE TEST THE SAMPLE DISTRIBUTION FOR GOODNESS 1004
C      OF FIT TO A NORMAL, LOG-NORMAL, AND WEIBULL DISTRIBUTION FUNCTION 1005
      DIMENSION A(1000),JCEL(100),Z(47),C(47) 1006
      COMMON/CZ/Z,C 1007
      DATA (Z(I),I=1,47)/ 1008
1-1000.,-5.,-4.,-3.4,-3.2,-3.,-2.9,-2.8,-2.7,-2.6 1009
2,-2.5,-2.3,-2.1,-2.0,-1.8,-1.6,-1.4,-1.2,-1.0,-0.8,-0.6,-0.4,-0.2,1010
30.,0.2,0.4,0.6,0.8,1.0,1.2,1.4,1.6,1.8,2.0,2.1,2.3,2.5,2.6,2.7,2.81011
4,2.9,3.0,3.2,3.4,4.0,5.0,1000.0/ 1012
      DATA (C(I),I=1,47)/ 1013
1 0.,0.0000006,0.00006,0.0003,0.0007,0.0013,0.0019 1014
2,0.0026,0.0035,0.0047,0.0062,0.0107,0.0179,0.0228,0.0359,0.0548, 1015
3 0.0808,0.1151,0.1587,0.2119,0.2743,0.3446,0.4207,0.5000,0.5793, 1016
4 0.6554,0.7257,0.7881,0.8413,0.8849,0.9192,0.9452,0.9641,0.9772, 1017
5 0.9821,0.9893,0.9938,0.9953,0.9965,0.9974,0.9981,0.9987,0.9993, 1018
6 0.9997,0.99994,0.9999994,1.0/ 1019
      PN=N 1020
      NPARM=4 1021
      IF(LD.LE.0) NPARM=3 1022
      XN=NG 1023
      AB=A(10) 1024
      AT=A(N-9) 1025
      DU=(AT-AB)/(XN-2.) 1026
      DO 10 J=1,NG 1027
10 JCEL(J)=0 1028
      JCEL(1)=10 1029
      JCEL(NG)=10 1030
      NR=N-10 1031
C      COUNT THE NUMBER OF VALUES IN EACH GROUP 1032
      DO 40 J=11,NR 1033
      X=A(J)-AB 1034
      IF(X) 20,30,30 1035

```

20	IC=1	1036
	GO TO 40	1037
30	IC=X/DU+2	1038
	IF(IC.GT.NG) IC=NG	1039
40	JCEL(IC)=JCEL(IC)+1	1040
C	CALCULATE PROBABILITIES WITH EACH GROUP AND COMPARE ACTUAL WITH EX	1041
C	SPECTED FREQUENCY AND COMPUTE CHI-SQUARED VALUE CS	1042
C	COMPUTE LOWER CELL PROBABILITY	1043
	XL=-1.E10	1044
	XU=AB	1045
	M=1	1046
	FE=PN*PZC(XL,XU,AM,AS,WA,WB,WC,LD,M)	1047
	FA=JCEL(1)	1048
	CS=((FA-FE)*(FA-FE))/FE	1049
C	COMPUTE UPPER CELL PROBABILITY	1050
	XL=AT	1051
	XU=1.E10	1052
	M=46	1053
	FE=PN*PZC(XL,XU,AM,AS,WA,WB,WC,LD,M)	1054
	FA=JCEL(NG)	1055
	CS=CS+((FA-FE)*(FA-FE))/FE	1056
	NL=NG-1	1057
	XL=AB	1058
	M=1	1059
	DO 50 J=2,NL	1060
	XU=XL+DU	1061
	FE=PN*PZC(XL,XU,AM,AS,WA,WB,WC,LD,M)	1062
	FA=JCEL(J)	1063
	CS=CS+((FA-FE)*(FA-FE))/FE	1064
50	XL=XU	1065
C	TEST CHI-SQUARED VALUE FOR LEVEL OF SIGNIFICANCE	1066
	F=NG-NPARM	1067
	B=2./(9.*F)	1068
	ZT=(1.-B-(CS/F)**0.3333333333)/SQRT(B)	1069

M=1  
CALL TBLN(CR,ZT,Z,C,47,M)  
RETURN  
END

1070  
1071  
1072  
1073

*DECK CYCLE	1074
SUBROUTINE CYCLE (THEC,GR,DR,H,T1,T2,DC,A,NDOVER,FCT)	1075
C SUBROUTINE FOR COMPUTING THE LIMIT CYCLE	1076
C THEC=CONTROL ACCELERATION	1077
C GR=RATE TO DISPLACEMENT GAIN RATIO	1078
C DR=DEADBAND HALFWIDTH	1079
C H=HYSTERSIS	1080
C T1=EFFECTIVE TURN ON DELAY TIME	1081
C T2=EFFECTIVE TURN OFF DELAY TIME	1082
C DC=DUTY CYCLE	1083
C A=LIMIT CYCLE RATE	1084
C NDOVER=0 FOR NO DEADBAND OVERSHOOT	1085
C =1 FOR DEADBAND OVERSHOOT CONDITION	1086
C IF FCT IS GREATER THAN ZERO, PULSE WIDTH IS ESTIMATED AND USED	1087
C TO ESTIMATE EFFECTIVE CONTROL ACCELERATION	1088
NDOVER=0	1089
FK=1.0	1090
D=DR/57.3	1091
TDD=ABS(THEC)	1092
K=0	1093
IF (FCT .LE. 0 ) GO TO 10	1094
K=1	1095
10 A=(TDD*T2*(GR-T2/2.)+D*H)/(2.*GR-T1-T2)	1096
ALPHA=D*(2.*GR-T1-T2-H*(GR-T1/2.))/(T2*(GR-T2/2.)*(GR-T1/2.))	1097
IF (TDD-ALPHA .LE. 0 ) GO TO 20	1098
NDOVER=1	1099
C DUTY CYCLE APPROXIMATION FOR DEADBAND OVERSHOOT	1100
H=H/2.	1101
AD=2.*D*(1.0-H)/(TDD*GR)	1102
DNOM=(T1-T2+AD)/(2.*T2-AD+((AD/2.+T2-AD)*(T1-T2+AD)/GR))	1103
DC=1./(1.+DNOM)	1104
GO TO 30	1105
C COMPUTE DUTY CYCLE WITHOUT DEADBAND OVERSHOOT	1106
20 DC=FK/(1.+TDD*(D/A+T1-GR)/A)	1107

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IF (K .LE. 0 ) GO TO 30
PU=2.*A/TDD
FK=1.0+FACT/PU
TDD=ABS(THC*FK)
K=0
GO TO 10
30 RETURN
END

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1108
1109
1110
1111
1112
1113
1114
1115

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*DECK HISTO	1116
SUBROUTINE HISTO (X,N,XMAX,XMIN,DX)	1117
C THIS SUBROUTINE SORTS AND PLOTS A HISTOGRAM ON THE LINE PRINTER	1118
C X=ARRAY OF SAMPLES	1119
C N=NUMBER OF SAMPLES IN ARRAY	1120
C XMAX=MAXIMUM VALUE	1121
C XMIN=MINIMUM VALUE	1122
C DX=INCREMENT FOR EACH CELL	1123
C K=NUMBER OF SAMPLES IN EACH CELL	1124
DIMENSION X(1),KAXIS(94)	1125
DATA ISTAR,IBLANK/1H*,1H /	1126
C PRINT NUMBER OF SAMPLES, MIN AND MAX VALUES	1127
WRITE( 6,110) N,X(1),X(N)	1128
L=1	1129
K=0	1130
AX1=XMIN	1131
10 AX2=AX1+DX	1132
DO 20 J=L,N	1133
IF (X(J)-AX2 .GE. 0 ) GO TO 30	1134
K=K+1	1135
20 CONTINUE	1136
30 IF (K-94 .GE. 0 ) GO TO 50	1137
K1=K+1	1138
DO 40 J=K1,94	1139
40 KAXIS(J)=IBLANK	1140
K2=K	1141
IF (K .LE. 0 ) GO TO 80	1142
GO TO 60	1143
50 K2=94	1144
60 DO 70 J=1,K2	1145
70 KAXIS(J)=ISTAR	1146
80 WRITE( 6,100) AX1,AX2,K,(KAXIS(J),J=1,94)	1147
IF (AX2-XMAX .GE. 0 ) GO TO 90	1148
L=L+K	1149



K=0	1150
AX1=AX2	1151
GO TO 10	1152
90 RETURN	1153
100 FORMAT (1X,F6.2,* TO*,F7.2,I5,* I*,94A1,*I*)	1154
110 FORMAT (1X,*NO OF SAMPLES=*,I5,* MIN=*,F6.2,* MAX=*,F7.2,/4X,*RA	1155
1NGE           NUMBER 0     5     10     15     20     25     30     35     40     45	1156
2 50     55     60     65     70     75     80     85     90     95*,/23X,*I....I....	1157
3I....I....I....I....I....I....I....I....I....I....I....I....I....I....I....	1158
4....I....I....I....I*)	1159
END	1160

*DECK OVRF	1161
C THIS SUBROUTINE COMPUTES A FACTOR(FAC) ON CONTROL MOTOR	1162
C THRUST FOR SHORT PULSES OF AN OVERSHOOT RESPONSE	1163
C T = TIME FROM ZERO THRUST TO FIRST OVERSHOOT PEAK	1164
C OR= THRUST OVERSHOOT RATIO FMAX/FPEAK	1165
SUBROUTINE OVRF (T,OR,FAC)	1166
A=0.31831*ALOG(1.0/(OR-1.0))	1167
P=ATAN(1.0/A)	1168
W=6.2832/T	1169
FAC=(1.570796-0.5*P-SIN(2.*P))/W	1170
RETURN	1171
END	1172

*DECK PAGEHD	1173
SUBROUTINE PAGEHD (NRUN,NPAGE,NLINE)	1174
C    THIS SUBROUTINE EJECTS AN OUTPUT PAGE AND PRINTS RUN NO.	1175
C    AND PAGE NO. AT THE TOP OF EACH NEW PAGE	1176
WRITE( 6,10)	1177
WRITE( 6,20) NRUN,NPAGE	1178
NLINE=5	1179
RETURN	1180
10 FORMAT (1H1)	1181
20 FORMAT (5X,7HRUN NO.,I5,54X,8HPAGE NO.,I5)	1182
END	1183

*DECK	PZC	1184
	FUNCTION PZC(XL,XU,AM,AS,WA,WB,WC,LD,M)	1185
	COMMON/CZ/Z(47),C(47)	1186
C	THIS FUNCTION SUBPROGRAM COMPUTES THE PROBABILITY OF A VALUE	1187
C	BETWEEN A LOWER AND UPPER LIMIT FOR A NORMAL OF WEIBULL	1188
C	DISTRIBUTION	1189
	IF(LD.GT.0) GO TO 10	1190
C	NORMAL DISTRIBUTION PROBABILITY	1191
	SF=(XL-AM)/AS	1192
	CALL TBLN(P1,SF,Z,C,47,M)	1193
	SF=(XU-AM)/AS	1194
	CALL TBLN(P2,SF,Z,C,47,M)	1195
	PZC=P2-P1	1196
	RETURN	1197
C	WEIBULL DISTRIBUTION PROBABILITY	1198
10	P1=0.	1199
	IF(XL-WA) 20,20,15	1200
15	AG=((XL-WA)/WB)**WC	1201
	P1=1.-EXP(-AG)	1202
20	P2=0.	1203
	IF(XU-WA) 30,30,25	1204
25	AG=((XU-WA)/WB)**WC	1205
	P2=1.	1206
	IF(AG.GT.100) GO TO 30	1207
	P2=1.-EXP(-AG)	1208
30	PZC=P2-P1	1209
	RETURN	1210
	END	1211

*DECK RANGE	1212
SUBROUTINE RANGE (X,N,XMAX,XMIN,DX,NDX,ERRTB)	1213
C THIS SUBROUTINE DIVIDES THE RANGE OF A TABLE OF NUMBERS INTO	1214
C N OR GREATER EQUAL PARTS WITH ESTHETICALLY PLEASING SCALES	1215
C TEST FOR INCREASING OR DECREASING FUNCTION. IF DECREASING	1216
C THE TABLE IS CHANGED TO AN INCREASING ARRANGEMENT	1217
C X = INPUT ARRAY	1218
C N = NUMBER OF VALUES IN ARRAY	1219
C XMAX= UPPER END OF LAST CELL	1220
C XMIN= LOWEST VALUE	1221
DIMENSION X(1)	1222
ERRTB=0	1223
C TEST FOR ASCENDING OR DESCENDING ARRAY	1224
IF (X(1)-X(N)) 40,10,20	1225
10 ERRTB=1	1226
RETURN	1227
C DECREASING ARRAY, CHANGE TO ASCENDING ORDER	1228
20 LN=N/2	1229
DO 30 J=1,LN	1230
Z=X(J)	1231
NF=N+1-J	1232
X(J)=X(NF)	1233
30 X(NF)=Z	1234
C COMPUTE AESTHETICALLY PLEASING INCREMENTS OVER RANGE	1235
40 XMIN=X(1)	1236
XMAX=X(N)	1237
DELT=XMAX-XMIN	1238
ZDX=NDX	1239
XINC=DELT/ZDX	1240
XLIN=ALOG10(XINC)	1241
LIN=XLIN	1242
IF (XLIN .GE. 0 ) GO TO 50	1243
LE=-LIN+1	1244
GO TO 60	1245

C		1247
	50 LE=-LIN	1248
	60 MINC=XINC*(10.**LE)	1249
	IF (MINC-5 .LT. 0 ) GO TO 70	1250
	XINC=5./((10.**LE)	1251
	GO TO 100	1252
	70 IF (MINC-4 .LT. 0 ) GO TO 80	1253
	XINC=4./((10.**LE)	1254
	GO TO 100	1255
	80 IF (MINC-2 .GE. 0 ) GO TO 90	1256
	XINC=1./((10.**LE)	1257
	GO TO 100	1258
	90 XINC=2./((10.**LE)	1259
	100 DX=XINC	1260
C	COMPUTE START AND FINISH XMIN AND XMAX	1261
	R=XMIN/XINC	1262
	KAR=ABS(R)	1263
	KR=R	1264
	XKAR=KAR	1265
C	TEST FOR FIRST CELL STARTING VALUE	1266
	IF (KR .NE. 0 ) GO TO 130	1267
	IF (R .LT. 0 ) GO TO 120	1268
	110 XMIN=0.	1269
	GO TO 160	1270
	120 XMIN=-XINC	1271
	GO TO 160	1272
C	COMPUTE NON-ZERO MINIMUM STARTING CELL LOCATION	1273
	130 IF (R) 140,110,150	1274
	140 XMIN=-(XKAR+1.)*XINC	1275
	GO TO 160	1276
	150 XMIN=XINC*(XKAR-1.)	1277
C	END CELL LOCATION	1278
	160 XMAX=X(N)+XINC	1279
	RETURN	1280
	END	1281

*DECK RNDX	1282
SUBROUTINE RNDX (JK)	1283
C    SUBROUTINE FOR COMPUTING THE RANDOM NORMAL DEVIATE	1284
C    RANF IS CDC BUILT-IN PSUEDO-RANDOM NUMBER GENERATOR	1285
C    K IS THE CURRENT RANDOM SEQUENCE INTEGER WHICH CHANGES	1286
C    WITH EACH NEW RANDOM NUMBER GENERATION	1287
COMMON K,RXD(30)	1288
DO 30 I=1,JK	1289
Q=RANF(K)	1290
C THE FOLLOWING CODING WILL GIVE A SUITABLE REPLACEMENT FOR RANF	1291
C    KA=K*23	1292
C    JJ=1.0E+7	1293
C    N=KA/JJ	1294
C    M=N*JJ	1295
C    K=KA-M-N	1296
C    AK=K	1297
C    Q=1.0E-7*AK	1298
C IN THE ABOVE OPTION K SHOULD BE A 7 DIGIT NUMBER	1299
C    TRANSFORM 0-1 UNIFORM DISTRIBUTION TO -0.5 TO 0.5 UNIFORM	1300
IF (Q-.5 .LE. 0 ) GO TO 10	1301
Q=1.0-Q	1302
AB=-1.0	1303
GO TO 20	1304
10 AB=1.0	1305
C    TRANSFORM UNIFORM TO GAUSSIAN N(0,1)	1306
20 XPT=-2.*ALOG(Q)	1307
XRT=ABS(XPT)	1308
Y=SQRT(XRT)	1309
D=2.515517+.802853*Y+.010328*Y*Y	1310
E=1.0+1.432788*Y+.189269*Y*Y+.001308*Y*Y*Y	1311
C    COMPLETE TRANSFORMATION TO GET RANDOM NORMAL DEVIATE	1312
30 RXD(I)=AB*(Y-(D/E))	1313
RETURN	1314
END	1315

*DECK RUNGE	1316
SUBROUTINE RUNGE (L,I)	1317
C    THIS SUBROUTINE PERFORMS THE RUNGE-KUTTA INTEGRATION IN	1318
C    COMBINATION WITH THE CALCU SUBROUTINE	1319
DIMENSION RAT(4),SAU(4)	1320
COMMON/DDY/YDOT(4),Y(4),T,DT	1321
I=I+1	1322
GO TO (10,20,40,60,80), I	1323
10  L=1	1324
RETURN	1325
20  DO 30 J=1,3	1326
SAU(J)=Y(J)	1327
RAT(J)=YDOT(J)	1328
30  Y(J)=SAU(J)+0.5*DT*YDOT(J)	1329
T=T+0.5*DT	1330
L=1	1331
RETURN	1332
40  DO 50 J=1,3	1333
RAT(J)=RAT(J)+2.*YDOT(J)	1334
50  Y(J)=SAU(J)+0.5*DT*YDOT(J)	1335
L=1	1336
RETURN	1337
60  DO 70 J=1,3	1338
RAT(J)=RAT(J)+2.*YDOT(J)	1339
70  Y(J)=SAU(J)+DT*YDOT(J)	1340
T=T+0.5*DT	1341
L=1	1342
RETURN	1343
80  DO 90 J=1,3	1344
90  Y(J)=SAU(J)+(DT/6.)*(RAT(J)+YDOT(J))	1345
L=2	1346
I=0	1347
RETURN	1348
END	1349



*DECK	TABGEN	1350
	SUBROUTINE TABGEN (Q0,U0,GAM0)	1351
C	THIS SUBROUTINE PROPAGATES THE TRAJECTORY PARAMETERS	1352
C	VELOCITY,DYNAMIC PRESSURE, GAMMA, AND ALTITUDE DURING	1353
C	A GRAVITY TURN BOOST. INITIAL VELOCITY AND DYNAMIC	1354
C	PRESSURE ARE USED TO DETERMINE ALTITUDE. THRUST, WEIGHT	1355
C	DRAG COEFFICIENT AND INITIAL FLIGHT PATH ANGLE(GAMMA) ARE	1356
C	USED TO SOLVE THE EQUATIONS OF MOTION USING THE RUNGE	1357
C	AND CALCU SUBROUTINES. RETURNED TABLES ARE VIA COMMON DOUT	1358
	DIMENSION DUM(90)	1359
	COMMON/DOUT/NQT,TBL1(90),NUT,TBL5(90),NGT,TBL6(90),NHT,	1360
1	TBL11(90),TF,NTC,TBL4(90)	1361
	COMMON/DRH/RHO(18),MRH	1362
	COMMON/DDI/TBL2(90),TBL3(90),NTHT,NUT,CDS,M2,M3,WB0	1363
	COMMON/DDY/YDOT(4),Y(4),T,DT	1364
	DATA DT,NP/0.5,4/	1365
C	RHO IS A TABLE OF Z,P,Z,P,Z,P VALUES WHERE	1366
C	Z = ALTITUDE IN FEET	1367
C	P = NATURAL LOG OF INVERSE ATMOSPHERIC DENSITY(SLUGS/FT3)	1368
C	ALOG(1/DENSITY)	1369
	DATA (RHO(J),J=1,18)/0.,6.042,100000.,10.3417,120000.,	1370
1	11.271,140000.,12.1335,160000.,12.9239,200000.,14.3163,	1371
2	240000.,15.8823,328000.,20.665,557700.,27.256/	1372
	DO 10 J=1,4	1373
10	YDOT(J)=0.	1374
	MRH=1	1375
	M2=1	1376
	M3=1	1377
C	COMPUTE INITIAL ALTITUDE FROM VELOCITY AND DYNAMIC PRESSURE	1378
	CALL ALTI (ALTO,U0,Q0)	1379
	T=0.	1380
	KP=NP	1381
C	SET INITIAL TRAJECTORY STATES	1382
	Y(1)=U0	1383

	Y(2)=ALTO	1384
	Y(3)=GAMO	1385
	Y(4)=QO	1386
C	BEGIN INTEGRATION LOOP AND FILLING OF TABLES	1387
20	IF (KP-NP .LT. 0 ) GO TO 30	1388
	NQT=NQT+2	1389
	NTQ1=NQT-1	1390
	TBL1(NTQ1)=T	1391
	TBL5(NTQ1)=T	1392
	TBL6(NTQ1)=T	1393
	TBL11(NTQ1)=T	1394
	TBL11(NQT)=Y(2)	1395
	TBL6(NQT)=Y(3)	1396
	TBL5(NQT)=Y(1)	1397
	TBL1(NQT)=Y(4)	1398
	KP=0	1399
30	KP=KP+1	1400
	I=0	1401
C	CALL RUNGE-KUTTA INTEGRATION SUBROUTINE	1402
40	CALL RUNGE (L,I)	1403
	IF (L.EQ.2) GO TO 50	1404
C	CALL STATE EQUATION UPDATE SUBROUTINE	1405
	CALL CALCU	1406
	GO TO 40	1407
50	CONTINUE	1408
	IF (T-TF .LE. 0 ) GO TO 20	1409
C	END OF INTEGRATION LOOP	1410
	NUT=NQT	1411
	NGT=NQT	1412
	NHT=NQT	1413
	MD=1	1414
C	CHANGE INPUT TABLE OF THETA-GAMMA TO NEW THETA TABLE	1415
	DO 60 J=2,NGT,2	1416
	T=TBL6(J-1)	1417

CALL TBLU (NTC,TH,T,TBL4,MD)	1418
DUM(J-1)=T	1419
60 DUM(J)=TH+TBL6(J)	1420
DO 70 J=1,NGT	1421
70 TBL4(J)=DUM(J)	1422
NTC=NGT	1423
RETURN	1424
END	1425

*DECK TBLN	1426
SUBROUTINE TBLN (Y,X,T,A,NT,M)	1427
C THIS SUBROUTINE IS A TABLE LOOKUP FROM ABSCISSA TABLE T	1428
C AND ORDINATE TABLE A . Y IS ORDINATE AT GIVEN ABSCISSA X.	1429
C NT IS LENGTH OF TABLES T AND A. MIS LOCATION OF LAST VALUE SOUGHT	1430
DIMENSION T(1),A(1)	1431
10 IF (T(M)-X) 50,20,30	1432
20 Y=A(M)	1433
RETURN	1434
30 IF (T(1)-X .LT. 0 ) GO TO 40	1435
M=1	1436
GO TO 20	1437
40 M=M-1	1438
GO TO 10	1439
50 MM=M+1	1440
IF (MM-NT .LE. 0 ) GO TO 60	1441
M=NT	1442
GO TO 20	1443
60 IF (T(MM)-X .GT. 0 ) GO TO 70	1444
M=MM	1445
GO TO 50	1446
70 M=MM-1	1447
DT=T(MM)-T(M)	1448
IF (DT .NE. 0 ) GO TO 80	1449
Y=A(M)	1450
RETURN	1451
80 DY=A(MM)-A(M)	1452
DDT=X-T(M)	1453
Y=A(M)+DY*DDT/DT	1454
RETURN	1455
END	1456

*DECK TBLU	1457
SUBROUTINE TBLU (NT,Y,X,T,M)	1458
C SINGLE TABLE LOOKUP SUBROUTINE	1459
C NT = NUMBER OF VALUES IN ARRAY	1460
C Y = RETURNED ORDINATE	1461
C X = ABSCISSA VALUE CALLED	1462
C T = INPUT TABLE OF ALTERNATING ABSCISSAS AND ORDINATES	1463
C ORDINATES MUST BE MONOTONICALLY INCREASING	1464
C M = PREVIOUS INDEX USED IN THIS TABLE LOOKUP	1465
C THIS INDEX GETS CHANGED TO CURRENT VALUE	1466
DIMENSION T(1)	1467
10 IF (T(M)-X) 50,20,30	1468
20 Y=T(M+1)	1469
RETURN	1470
30 IF (T(1)-X .LT. 0 ) GO TO 40	1471
M=1	1472
GO TO 20	1473
40 M=M-2	1474
GO TO 10	1475
50 MM=M+2	1476
IF (MM-NT-1 .LE. 0 ) GO TO 60	1477
M=NT-1	1478
GO TO 20	1479
60 IF (T(MM)-X .GT. 0 ) GO TO 70	1480
M=MM	1481
GO TO 50	1482
70 M=MM-2	1483
DT=T(MM)-T(M)	1484
IF (DT .NE. 0 ) GO TO 80	1485
Y=T(M+1)	1486
RETURN	1487
80 DY=T(MM+1)-T(M+1)	1488
DDT=X-T(M)	1489
Y=T(M+1)+DY*DDT/DT	1490
RETURN	1491
END	1492

*DECK	THEMIN	1493
	SUBROUTINE THEMIN (THEC,GR,DR,H,T1,T2,THMIN)	1494
C	SUBROUTINE FOR COMPUTING THE MINIMUM DISTURBING ACCELERATION	1495
C	RESULTING IN ONE SIDED LIMIT CYCLE MOTION	1496
C	THEC = CONTROL ACCELERATION	1497
C	GR = RATE TO DISPLACEMENT GAIN RATIO	1498
C	DR = DEADBAND HALFWIDTH	1499
C	H = HYSTERESIS	1500
C	T1 = EFFECTIVE TURN-ON DELAY TIME	1501
C	T2 = EFFECTIVE TURN-OFF DELAY TIME	1502
C	THMIN= MINIMUM ACCELERATION (RETURNED)	1503
	D=DR/57.3	1504
	A=2.*GR-T1-T2	1505
	B=(GR-T1/2.)*T1	1506
	C=(GR-T2/2.)*T2	1507
	Z=GR-T1	1508
	ABC=(B-C)/A	1509
	CA=C/A	1510
	Z2=(D*H+C*THEC)/A	1511
	Z22=(D*H-C*THEC)/A	1512
	APR=B-Z*ABC-.5*(GR*GR+ABC*ABC)	1513
	BPR=2.*D-Z*Z2-ABC*CA*THEC	1514
	CPR=(.5*Z22*Z22+ABC*D*H/A)/APR	1515
	XPR=.5*BPR/APR	1516
	ZPR=ABS(XPR*XPR+CPR)	1517
	ZPR2=SQRT(ZPR)	1518
	THMIN1=ABS(XPR+ZPR2)	1519
	THMIN2=ABS(XPR-ZPR2)	1520
	IF (THMIN1-THMIN2 .GE. 0 ) GO TO 10	1521
	THMIN=THMIN1	1522
	GO TO 20	1523
10	THMIN=THMIN2	1524
20	RETURN	1525
	END	1526

*DECK WBL	1527
SUBROUTINE WBL (N,Y,NG,F)	1528
C    THIS SUBROUTINE COMPUTES THE STATISTICAL DISTRIBUTION PARAMETERS	1529
C    MEAN, STANDARD DEVIATION, SKEWNESS, KURTOSIS, GOODNESS	1530
C    OF FIT TO NORMAL, LOG-NORMAL, AND WEIBULL	1531
DIMENSION Y(1),Q(20),R(18),S(24),X(1000),F(20)	1532
DATA (Q(I),I=1,20)/-0.95,3.46,	1533
1-0.87,3.0,-0.64,2.3,-0.37,1.8,-0.09,1.39,0.16,1.1,0.63,0.7,0.93,	1534
20.5,1.52,0.2,2.0,0.001/	1535
DATA (R(I),I=1,18)/0.,-0.001,0.4,-0.95,0.8,	1536
1-1.7,1.2,-2.43,1.8,-3.48,2.4,-4.55,3.0,-5.65,3.66,-6.92,4.5,-8.5/	1537
DATA (S(I),I=1,24)/0.,1.,0.2,0.932,0.4,0.902,0.6,0.888,0.8,0.886	1538
1,1.1,0.893,1.8,0.9275,2.2,0.947,2.6,0.963,3.0,0.974,3.5,	1539
2 0.984,4.5,0.994/	1540
MQ=1	1541
MR=1	1542
MS=1	1543
AUI=N-1	1544
XK=1./SQRT(1.-1.96*SQRT(2./AUI))	1545
NQ=20	1546
NR=18	1547
NS=24	1548
AN=N	1549
S1=0.	1550
S2=0.	1551
S3=0.	1552
S4=0.	1553
DO 10 J=1,N	1554
X(J)=Y(J)	1555
10    S1=S1+X(J)	1556
C    COMPUTE THE MEAN VALUE	1557
XM=S1/AN	1558
DO 20 J=1,N	1559
DX=(X(J)-XM)	1560

	DS=DX*DX	1561
	S2=S2+DS	1562
	S3=S3+DS*DX	1563
20	S4=S4+DS*DS	1564
C	COMPUTE THE VARIANCE, SKEWNESS, KURTOSIS, AND STANDARD DEVIATION	1565
	VAR=S2/AN	1566
	SKEW=(S3/AN)/(VAR**1.5)	1567
	SKUR=(S4/AN)/(VAR*VAR)	1568
	SIG=SQRT(VAR)	1569
C	COMPUTE THE A,B,C PARAMETERS FOR A WEIBULL DISTRIBUTION FUNCTION	1570
	CALL TBLU (NQ,CL,SKEW,Q,MQ)	1571
	C=EXP(CL)	1572
	CALL TBLU (NR,BL,CL,R,MR)	1573
	B=SQRT(VAR/EXP(BL))	1574
	CALL TBLU (NS,A1,CL,S,MS)	1575
	A=XM-B*A1	1576
	OC=1./C	1577
	F(1)=XM	1578
	F(2)=SIG	1579
	F(3)=SKEW	1580
	F(4)=SKUR	1581
	F(9)=XM+XK*2.576*SIG	1582
	F(11)=A	1583
	F(12)=B	1584
	F(13)=C	1585
	F(14)=A+B*(0.694**OC)	1586
	F(15)=A+B*(4.6**OC)	1587
	F(16)=A+B*(5.3**OC)	1588
	F(17)=A+B*(6.9**OC)	1589
C	USE CHI-SQUARED GOODNESS OF FIT TEST TO ESTIMATE LEVEL OF	1590
C	SIGNIFICANCE (CR)	1591
C	TEST WEIBULL DISTRIBUTION	1592
	CALL CHISQ (N,X,CR,NG,XM,SIG,A,B,C,1)	1593
	F(20)=CR	1594



C	TEST NORMAL DISTRIBUTION	1595
	CALL CHISQ (N,X,CR,NG,XM,SIG,A,B,C,0)	1596
	F(18)=CR	1597
	S1=0.	1598
	S2=0.	1599
	S3=0.	1600
	S4=0.	1601
C	COMPUTE THE LOGARITHM OF VALUES	1602
	DO 30 J=1,N	1603
	X(J)=ALOG(Y(J))	1604
30	S1=S1+X(J)	1605
	XM=S1/AN	1606
	DO 40 J=1,N	1607
	DX=(X(J)-XM)	1608
	DS=DX*DX	1609
	S2=S2+DS	1610
	S3=S3+DS*DX	1611
40	S4=S4+DS*DS	1612
	VAR=S2/AN	1613
	SIG=SQRT(VAR)	1614
	SKEW=S3/(AN*VAR**1.5)	1615
	SKUR=S4/(AN*VAR*VAR)	1616
	F(5)=XM	1617
	F(6)=SIG	1618
	F(7)=SKEW	1619
	F(8)=SKUR	1620
	F(10)=EXP(XM+XK*2.576*SIG)	1621
C	TEST LOG-NORMAL DISTRIBUTION FOR LEVEL OF SIGNIFICANCE	1622
	CALL CHISQ (N,X,CR,NG,XM,SIG,A,B,C,0)	1623
	F(19)=CR	1624
	RETURN	1625
	END	1626

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16 Abstract <p>This report describes a FORTRAN coded computer program and method to predict the reaction control fuel consumption statistics for a three axis stabilized rocket vehicle upper stage. It uses a Monte Carlo approach which is made more efficient by using closed form estimates of impulse useage. It includes effects of rocket motor thrust misalignment, static unbalance, aerodynamic disturbances, and deviations in trajectory, mass properties and control system characteristics. This routine has been used for over a decade to accurately predict the control fuel consumption statistics for the Scout launch vehicle second and third-stage reaction control systems.</p> <p>By selection of input data and options this routine can be applied to many types of on-off reaction controlled vehicles.</p> <p>The psuedo random number generation and statistical analyses subroutines including the output histograms can easily be used for other Monte Carlo analyses problems.</p> <p>A typical run of 200 samples requires 2 seconds of central processor time on a CDC CYBER 175 computer.</p>					
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